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THE

HAND-BOOK

OF

HOUSEHOLD SCIENCE.

A POPULAR ACCOUNT OF

HEAT, LIGHT, AIR, ALIMENT, AND CLEANSING,

IN

THEIR SCIENTIFIC PRINCIPLES AND DOMESTIC APPLICATIONS.

WITH NUMEROUS ILLUSTRATIVE DIAGRAMS.

ADAPTED FOR ACADEMIES, SEMINARIES, AND SCHOOLS.

BY

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PREFACE.

A DESIRE to prepare a better statement than has hitherto been offered, of the bearings of science upon the economy of the household, has led to the following work. The purpose has been, to condense within the limits of a convenient manual the largest possible amount of interesting and valuable scientific information of those agents, materials, and operations in which we have a concern, chiefly as dwellers in houses.

The subjects are treated somewhat in an elementary way, but with constant reference to their domestic and practical relations. Principles are universal; their applications are special and peculiar. There are general laws of light, heat, and air, but they may be studied in various connections. There are many things about them which a person, as a resident of a house, cares little to know; while there are others in which he has a profound interest. To consider these, we assume to be the province of *household science.* The question of moisture in the air, for example, is one of universal scientific interest to meteorologists; but it has also a special and vital import for the occupants of stove and furnace heated rooms. Different colors, when brought together, alter and modify each other according to a simple and beautiful law; and the Painter, the Decorator, and the Dyer, have each a technical interest in the principle; but hardly more than the Lady at her toilette or engaged in furnishing her house. The Agriculturist is interested in the composition of food, as a *producer;* the Householder equally, as a *consumer.* The

Doctor must know the constituents of air and its action upon the living system for professional purposes, and he studies these matters as parts of his medical education; but for the same reasons of life and death, the inhabitants of houses are concerned to understand the same things.

These examples illustrate the leading conception of the present work. Its preparation has been attended with grave difficulties. Of course, a volume of this compass can present only a compend of the subjects it considers. Heat, light, air, and aliment are topics of large extent, wide and complex in their principles, which are of boundless application. We do not profess to have treated them with any completeness, but only to have brought distinctly forward those aspects which have been formerly too much neglected. In deciding what to state, and what to omit, we have been guided by two rules; *first*, to present such facts and principles as have the directest bearing upon household phenomena; and, *second*, to bring into prominence many important things not found in common books nor included in the ordinary range of school study. As elementary principles may be found fully treated elsewhere, we have been brief in their statement, thus gaining opportunity for important hints and views not generally accessible. Our chemistries are deficient in information of the composition and properties of food, while the physiological class-books are equally meagre in statements of its effects; we have accordingly dwelt upon these points with something of the fulness which their importance demands. So with heat, light, and air. It is hoped that the following pages will vindicate the fidelity with which we have labored to enrich the volume with new and valuable facts and suggestions, not procurable in our family manuals or school class-books. Many of the subjects presented have recently undergone searching investigation. They are rapidly progressive; facts are multiplying, and views widening. We have spared no pains to give the latest and most authentic results. Although the volume is to a great extent self-explanatory, and adapted for family and general reading, yet in the proper order of school

study it will find its most appropriate place after a course of elementary lessons in chemistry and physiology.

We have striven to present the subject in such a manner as to make reading and study both agreeable and instructive. Technical terms constitute a formidable obstacle, on the part of many, to the perusal of scientific books. This is a very serious difficulty, and requires to be managed as best we can. In works designed for general use they should be avoided as far as possible, and yet it is out of the question to think of escaping them entirely. If we would enjoy the thoughts of science we require to learn at least a portion of the language in which alone these thoughts are conveyed. The new objects and relations must be named, or they cannot be described and considered. We have studiously avoided obstructing the course of the common reader with many technical words, yet there are some which it was impossible to omit. The terms carbon, oxygen, hydrogen, nitrogen, carbonic acid, and some others, though hardly yet familiarized in popular speech, must soon become so. They are the names of substances of universal interest and importance; the chief elements of air, water, food, and organized bodies by which Providence carries on the mighty scheme of terrestrial activity and life. They are the keys to a new department of intellectual riches—the latest revelation of time respecting the conditions of human existence. The time has come when all who aspire to a character for real intelligence, must know something of the objects which these terms represent.

As respects the body of its facts and principles, any work of this kind must necessarily be of the nature of a compilation. We make no claim to discovery. The materials of the volume —the result of laborious and life-long investigations of many men—have been gathered from numberless sources,—from standard books upon the various topics, scientific magazines, original memoirs, personal correspondence, observation, household experience and laboratory examinations. Constant reference is made to authorities followed, and the language of others employed whenever it appeared to convey the most

suitable statement. Exemption from errors can hardly be expected in a work of this kind—errors of oversight and errors of judgment. Besides, many of its questions are in an unsettled state and involve conflicting views. Yet the utmost care has been taken to make an accurate and reliable presentation of the subjects considered.

The Author desires to acknowledge his indebtedness to his sister, Eliza A. Youmans, for constant and invaluable aid in the preparation of the work, not only in various experimental operations incident to its progress, but also in several parts of its literary execution. To his friend Mr. Richard H. Manning, who, though engaged in absorbing mercantile pursuits, has yet found time for thought in the direction of science and its applications, his thanks are due for valuable suggestions and important manuscript corrections.

If the work shall serve, in however small a degree, to excite thought, to give additional interest to household phenomena, and awaken a stronger desire for domestic improvement, the labor of its preparation will not have been performed in vain.

New York, *August*, 1857.

INTRODUCTION.

WHEN a work is presented, claiming place in a systematic course of school study, two questions at once arise in the mind of the discriminating educator: *first*, what is the nature, rank, and value of the knowledge it imparts? and, *second*, what will be its general influence upon the mind of the student? In this twofold connexion there are some thoughts to which we solicit the reader's earnest and considerate attention.

The present volume has been prepared under a conviction that the knowledge it communicates is first in the order of importance among things to be considered by rational and civilized people. "Every man's proper mansion-house and home," says SIR HENRY WOTTON, "is the theatre of his hospitality, the seat of self-fruition, the comfortablest part of his own life, the noblest of his son's inheritance, a kind of private princedom; nay, to the possessors thereof an epitome of the whole world." Nothing needs to be added in eulogy of the household home, the place of life's purest pleasures and sweetest experiences, the perpetual rallying point of its hopes and joys. Whatever can render it more pleasant or attractive, or invest it with a new interest, or in any way improve or ennoble it, is at once commended to our sympathy and regard. To consider all the agencies which influence the course and character of household life, is far from the object of the present work. Our concern is chiefly with its more material circumstances and conditions. That we should understand something of the wonderful physical agencies which have control of our earthly being, and which are so incessantly illustrated in the dwelling, and be at least partially acquainted with those fixed natural ordinances upon which our daily welfare, comfort, health, and even life, immediately depend, must certainly be acknowledged by all. One of the most startling facts of man's history is, that placed in a world of immutable order, and endowed with such exalted gifts of understand-

ing and reason, he should yet have contrived to maintain so dense and perfect an ignorance of himself and the familiar objects by which he is surrounded. That exact knowledge of the ways of nature which puts her powers at human command, and bears the daily fruit of substantial improvement and universal beneficence, would seem to be the last and noblest achievement of mind; a fruition of long intellectual growth, the highest form in the latest time, after the preliminary and preparatory experience of ages. In its earlier strivings we observe the mind of man intently occupied with itself, and regarding material nature with unutterable disdain. It wandered aimless and dissatisfied in the misty regions of speculation. Its first great conquest was in the realm of abstraction, farthest removed from the vulgarities of mere matter—the discovery of mathematical principles. The earliest application of thought to physical subjects was away in the distant spheres, where imagination had revelled wildest from immemorial time, to the luminous points and mysterious movements of the heavens, which, according to PLATO, were most admirably fitted to illustrate geometry. The skies were mapped and charted long before the earth. COPERNICUS struck out the grand law of celestial circulation before HARVEY discovered that of the blood. The genius of NEWTON flashed an immortal light upon the mechanism of the universe, many years before RUMFORD began his humbler domestic investigations. Centuries have passed since the establishment of universal gravitation, while there are men now living who may recollect the most gigantic stride of modern science, the discovery of oxygen gas by PRIESTLY, and the earliest analysis of the air we breathe. Chemistry, which is the name given to the first serious grappling of human intelligence with all forms of common matter, belongs chiefly to our own century. This, too, has been progressive, and in its course has conformed to the general law we are indicating. Its earliest investigations were directed to inert mineral substances, stones and rocks; while the formal and systematic elucidation of those conditions and phases of matter in which we have the deepest interest—vegetable and animal compounds and processes, agricultural, physiological, and dietetical chemistry—is eminently an affair of our own day. Thus, the spirit of inquiry, at first recoiling from matter, and circling wide through metaphysical vacuities, gradually closed with the physical world, and now finds its last and highest inquest into the material conditions of man's daily life. The course of knowledge has been expansive, as well as progressive; from narrow views to universal principles; from empty speculations to world-wide utilities; from the pleasure of a few to

the advantage of the many; from utter ignorance and contempt of nature, to the revelation of all-embracing laws, and a beautiful and harmonious order in the commonest objects and operations of daily experience. To the truth of this general statement, the existence of the present book may be taken as a strong attestation. The mass of its facts and principles are the result of recent investigation. A hundred years ago such a work would have been, in all its essential features, a blank impossibility; indeed, it had lacked its richest materials if prepared for the last generation.

These facts should not be without their influence upon the scheme of popular education. It is its first duty to communicate that information which can be reduced to daily practice, and yield the largest measure of positive good. If recent inquiry has opened new treasures of available truth, it is bound to take charge of them for the general benefit. It must report the advance of knowledge, and keep pace with the progress of the human mind, or it is false to its trust. The subjects of study should be so modified and extended as to afford the largest advantage, intellectual and practical, of the labors of the great expounders of nature,—especially in those departments where knowledge can be made most useful and improving. A rational and comprehensive plan of education for all classes, which shall be based upon man's intrinsic and essential wants, and promptly avail itself of every new view and discovery in science, to enlighten him in his daily relations and duties, is the urgent demand of the time. Nor can it be always evaded. We are not to trundle round for ever in the old ruts of thought, clinging with blind fatuity to crude schemes of instruction, which belong, where they originated, with the bygone ages. He who has surrendered his life to the inanities of an extinct and exploded mythology, but who remains a stranger to God's administration of the living universe; who can skilfully rattle the skeletons of dead languages, but to whom the page of nature is as a sealed book, and her voices as an unknown tongue, is not always to be plumed with the supereminent designation of 'educated.'

There are many things, unquestionably, which it would be most desirable to study: but opportunity is brief, and capacity limited; and the acquisition of one thing involves the exclusion of another. We cannot learn every thing. The question of the relative rank of various kinds of knowledge—what shall be held of primary importance and what subordinate, is urgent and serious. As life and health are the first of all blessings, to maintain them is the first of all duties, and to understand their conditions the first of mental requirements.

Shall the thousand matters of mere distant and curious concernment be suffered to hold precedence of the solemn verities of being which are woven into the contexture of familiar life? The physical agents which perpetually surround, and act upon, and within us, heat, light, air, and aliment, are liable to perversion through ignorance, so as to produce suffering, disease, and death; or they are capable through knowledge of promoting health, strength, and enjoyment. What higher warrant can be asked that their laws and effects shall become subjects of general and earnest study. It may seem strange that in regard to the vital interests of life and health, man should be left without the natural guidance of instinct, and be driven to the necessity of reflection and study; that he for whom the earth seems made should be apparently less cared for in these respects than the inferior animals. Nevertheless, such is the divine ordination. Neither our senses, instincts, nor uninstructed faculties are sufficient guides to good, or guards from evil, in even the ordinary conditions of the civilized state. Things which most deeply affect our welfare, the senses fail to appreciate. They can neither discern the properties nor the presence of the most deadly agents. The breathing medium may be laden with noxious gases to the peril of life, and the senses fail to detect the danger. Hunger and thirst impel us instinctively to eat and drink, but they fail to inform us of the nutritive value of alimentary substances or their dietetical fitness to our varying requirements. For all those things which are independent of man's will, Providence has taken abundant care to provide; while in the domain of voluntary action, blind instinct is replaced by rational forecast. Whatever may have been those original conditions of bare animal existence which some yet sigh for, as the 'true state of nature,' we are far removed from them now. They have been successively disturbed as, generation after generation, intelligent ingenuity has been exercised to gain control of natural forces for the securing of comforts and luxuries, and to liberate man from the privations and drudgeries of the uncivilized condition. But unmingled good seems not permitted; the benefits are alloyed with evil. Thus, the introduction of the stove, while affording the advantage of economy and convenience in the management of fire, was a step backward in the matter of ventilation. Gas-lighting was a great advance on the methods of artificial illumination, but there came with it augmented contamination of the breathing medium and new dangers to the eyes. Against these and similar incidental mischiefs—'residues of evil' that accumulate against the predominating good, there is no other protection than intellect, instructed

in the material conditions which influence our health and life. For these, and kindred considerations of practical moment to all who occupy dwellings and assume civilized relations, we urge the study of *household science* as an essential part of general education.

It deserves to be better understood, that the highest value of science is derived from its power of advancing the public good. It is more and more to be consecrated to human improvement, as a sublime regenerative agency. Working jointly and harmoniously with the great moral forces of Christian Civilization, we believe it is destined to effect extensive social ameliorations. That it is not yet fully accepted in this relation is hardly surprising. The work of presenting scientific truth in those forms which may best engage the popular mind, is not to be fairly expected of those who give their lives to its original development. There is a deep satisfaction, an intrinsic compensating interest to the discoverer in the naked quest of truth, which is largely independent of any utility that may flow from the inquiry. In the exalted consciousness of achievement, the man of science finds an intellectual remuneration, so royal and satisfying that other considerations have comparatively little weight. Hence the indifference, to a great degree inevitable, with which original explorers contemplate the reduction of scientific principles to practical use. Moreover, this utter carelessness of results, where the mind is not biased, nor the vision blurred by ulterior considerations, is far the most favorable for successful investigation. Conscious that the effects of his labors are finally and always beneficial in society, the enthusiast of research may be excused his indifference to their immediate reception and uses. But the formal denial that the allegiance of mind is supremely due to the good of society is quite another affair. The sentiment too widely entertained in learned and educational circles, that knowledge is to be firstly and chiefly prized for its own sake, and the mental gratification it produces, we cannot accept. The view seems narrow and illiberal, and is not inspired of human sympathy. It took origin in times when the improvement of man's condition, his general education and elevation, were not dreamed of. It came from the ancient philosophy, which was not a dispensation of popular beneficence, an all-diffusive, ennobling agency in society, but confessed its highest aim to be a personal advantage, shut up in the individual soul. It was not radiant and outflowing like the sun, but drew all things inward, engulfing them in a malstrom of selfishness.

The baneful ethics of this philosophy have given place to the higher and more generous inculcations of Christianity, which lays upon human nature its broad and eternal requirement, 'to do good.' From

this authoritative moral demand science cannot be exempted. The power it confers is to be held and used as power is exercised by God himself, for purposes of universal blessing.

We place a high estimate upon the advantages which society may reap from a better acquaintance with material phenomena, for life is a stern realm of cause and effect, fact and law. To the poetic day-dreamer it may be an affair of sentiment, an 'illusion,' or a 'vapor,' but to the mass of mankind, life is a solid, unmistakable reality, that will not dissolve into mist and cannot be conjured out of its qualities. As such, we would deal with it in education, giving prominence to those forms of knowledge which will work the largest practical alleviations and most substantial improvement throughout the community. But it is wisely designed that those studies which may become in the highest degree useful are also first in intellectual interest. It is a grievous mistake to suppose that the study of natural science martyrizes the more ethereal faculties of the soul, and dooms the rest to painful toil among the naked sterilities of commonplace existence. So far from being unfriendly to the imagination, as is sometimes intimated, science is its noblest precursor and ally. Can that be unfavorable to this faculty, which infinitely multiplies its materials, and boundlessly amplifies its scope? Can that be restrictive of mental sweep, which unlocks the mysteries of the universe and pioneers its way far into the councils of Omniscience? Who was it that lifted the veil, and disclosed a new world of exquisite order and beauty in all the commonest and vulgarest forms of matter, below the former reach of eye or thought? Who was it that dissipated the fabulous 'firmament,' which primeval ignorance had mounted over its central and stationary earth; set the world in motion, and unfolded a plan of the heavens, so appalling in amplitude that imagination itself falters in the survey? Who was it that first read the handwriting of God upon the rocks, revealing the history of our planet and its inhabitants through durations of which the mind had never before even presumed to dream? In thus unsealing the mysteries of being—in turning the commonest spot into a museum of wonders—who can doubt that science has opened a new and splendid career for the play of the diviner faculties; and that its pursuit affords the most exhilarating, as well as the healthiest and purest of intellectual enjoyments? Nor should we forget its elevating tendencies; for in contemplating the varied scheme of being around, its beauties, harmonies, adaptations, and purposes of profoundest wisdom, the thoughts ascend in unspeakable admiration to the infinite Source of truth and light. We should educate and elevate our nature by these studies, storing our

minds with the richest materials of thought, enlarging our capacities of benign exertion, and rising to a more intimate communion with the spirit of the Great Maker of all.

But beyond these considerations, physical science has another claim upon the Instructor, in the kind and extent of the mental discipline it affords. The study of mathematics has a conceded value in this relation, being eminently favorable to precision and persistence of the mental operations—to steadfast concentration of thought upon abstract and difficult subjects. But we hope not to incur the charge of educational heresy, by expressing the opinion, that its training is somewhat defective—is neither sufficiently comprehensive, nor altogether of the right kind. Its influence is limited to certain faculties only, and the *method* to which it accustoms the mind is too little available in grappling with the practical problems of life. The starting-point of the mathematician is certain universal truths of consciousness, intuitive axioms—assumed without proof, because they are self-evident, and therefore incapable of proof. From these, by various operations and chains of reasoning, he proceeds to work out special applications. His direction is from generals to particulars—it is inferential—*deductive.* But when we come to deal with the phenomena of the external world, and the actualities of daily experience, this plan fails, and we are driven to the very reverse method. In the phenomenal world we are without the eternal principles, settled and assumed at the outset; these become themselves the objects of investigation; they have to be established, and we must begin with particulars, special inquiries, experimental investigations, the observation of facts, and from these we cautiously proceed to general truths—to universal principles. The process is an ascent from particulars — generalization—*induction.* That the whole is greater than a part, or that two parallel lines will never intersect each other, are irresistible intuitions, taken for granted at once by all minds. But that matter attracts matter with a force proportional to the square of its distance; or that chemical combination takes place in definite unalterable proportions, are truths of *induction*—general laws, only arrived at after long and laborious investigation of particular facts. These are essentially opposite methods of proceeding in different departments of inquiry, each correct in its own sphere, but false out of it. The human mind started with the mathematical method, and the greatest obstruction to the progress of physical science for many centuries arose from the attempt to apply it to outward phenomena; that is, to assume certain principles as true of the external world, and to reason from them down to the facts; in-

stead of beginning with the facts, and carefully evolving the general laws. The splendid achievements of modern science are the fruit of the inductive method. This should be largely joined with the mathematical to secure a full and harmonious mental discipline. It educates the attention by establishing habits of accurate observation, strengthens the judgment, teaches the supremacy of facts, cultivates order in their classification, and develops the reason through the establishment of general principles. It is claimed, as an advantage of mathematics, that it deals with certainties, and, raising the mind above the confusions and insecurities of imperfect knowledge, habituates it to the demand of absolute truth. That benefits may arise from this exalted state of intellectual requirement, we are far from doubting, and are conscious of the danger of resting satisfied with any thing short of perfect certitude, where that can be attained. But here again there is possibility of error. Mathematical standards and processes are totally inapplicable in the thousand-fold contingencies of common experience; and the mind which is deeply imbued with its spirit, is little attracted to those departments of thought, where, after the utmost labor, there still remain doubt, dimness, uncertainty and entanglement. And yet, such is precisely the practical field in which our minds must daily work. The mental discipline we need, therefore, is not merely a narrow deductive training of the faculties of calculation, with their inflexible demand for exactitudes; but such a systematic and symmetric exercise of its several powers as shall render it pliant and adaptive, and train it in that class of intellectual operations which shall best prepare it for varied and serviceable intellectual duty in the practical affairs of life.

There is still another thought in this connection which it is important should be expressed. It has been too much the policy of the past so to train the mind as to enslave, rather than to arouse it. Education, from the earliest time, has been under the patronage of civil and ecclesiastical despotisms, whose necessary policy has been the repression of free thought. The state of mind for ever insisted on has been that of submissive acceptance of authority. Instead of laying open the limitations, uncertainties, and conflicts of knowledge, which arise from its progressive nature, the spirit of the general teaching has been that all things are settled, and that wisdom has reached its last fulfilment. Instead of encouraging bold inquiry, and inciting to noble conquest, the effect has rather been to reduce the student to a mere tame, unquestioning recipient of established formulas and time-honored dogmas. It is obvious on all sides that this state

of things has been deeply disturbed. The introduction of Republicanism, with political freedom of speech and action; the advent of Protestantism, with religious liberty of thought; and the splendid march of science, which has enlarged the circle of knowledge, multiplied the elements of power, and scattered social and industrial revolution, right and left, for the last hundred years—these new dispensations have invaded the old repose, and fired the minds of multitudes with a new consciousness of power. Yet we cannot forget that our education still retains much of its ancient spirit, is yet largely scholastic and arbitrarily authoritative. We believe that this evil may be, to a considerable degree, corrected by a frank admission of the incompleteness of much of our knowledge; by showing that it is necessarily imperfect, and that the only just and honest course often involves reservation of opinion and suspension of judgment. This may be consonant neither with the teacher's pride nor the pupil's ambition, nevertheless it is imperatively demanded. We need to acquire more humility of mind and a sincerer reverence for truth; to understand that much which passes for knowledge is unsettled, and that we should be constant learners through life. The active influences of society, as well as the school-room, teach far other lessons. We are committed in early childhood to blind partisanships,—political and religious,—and drive on through life in the unquestioning and unscrupulous advocacy of doctrines which are quite as likely to be false as true, and are perhaps utterly incapable of honest definitive adjustment. Science inculcates a different spirit, which is most forcibly illustrated in those branches where absolute certainty of conclusion is difficult of attainment. Mr. Paget has urged the salutary influence of the study of physiology in this relation. He says, "It is a great hindrance to the progress of truth, that some men will hold with equal tenacity things that are, and things that are not, proved; and even things that, from their very nature, do not admit of proof. They seem to think (and ordinary education might be pleaded as justifying the thought) that a plain 'yes' or 'no' can be answered to every question that can be plainly asked; and that every thing thus answered is to be maintained as a point of conscience. I need not adduce instances of this error, while its mischiefs are manifested every where in the wrongs done by premature and tenacious judgments. I am aware that these are faults of the temper, not less than of the judgment; but we know how much the temper is influenced by the character of our studies; and I think if any one were to be free from this over-zeal of opinion, it should be

one who is early instructed in an uncertain science such as physiology.' In the present work, the chief statements comprised under heat, light, and air, may be regarded as settled with a high degree of certainty, while much of the matter relating to food and its effects is less clearly determined;—its truth is only approximative, and we have stated it, as such, without hesitation. While the reader is informed, he is at the same time apprised of the incompleteness of his knowledge.

An important result of the more earnest and general pursuit of science, by the young, will be, to find out and develop a larger number of minds having natural aptitudes for research and investigation. As there are born poets, and born musicians, so also there are born inventors and experimenters; minds originally fitted to combine and mould the plastic materials of nature into numberless forms of usefulness and value. It is a vulgar error that the work of discovery and improvement is already mainly accomplished. The thoughtful well understand that man has hardly yet entered upon that magnificent career of conquest, in the peaceful domain of nature, to which he is destined, and which will be hastened by nothing so much as a more general kindling of the minds of the young with enthusiasm for science. The harvest awaits the reapers—how strange that man should have neglected it so long. Fuel, air, water, and the metals, as we see them acting together, now, in the living, laboring steam-engine, have been waiting from the foundation of the world for a chance to relieve man of the worst drudgeries of toil. Long and fruitlessly did the sunbeam court the opportunity of leaving upon the earth permanent impressions of the things he revealed; while the lightning, though seemingly a lawless and rollicking spirit of the skies, was yet impatient to be pressed into the quiet and useful service of man. Can there be a doubt that other powers and forces, equally potent and marvellous, await the discipline of human genius? Not in vain was man called upon, at the very morning of creation, to 'subdue the earth.' Already has he justified the bestowment of the viceroyal honor: who shall speak of the possibilities that are waiting for him in the future!

THE

HAND-BOOK OF HOUSEHOLD SCIENCE.

PART FIRST.

HEAT.

I. SOURCES AND DISTRIBUTION OF TERRESTRIAL HEAT.

1. **Nature of our Knowledge concerning Heat.**—When we place the hand upon a stove with a fire in it, a feeling of warmth is experienced, while if it be made to touch ice, there is a sensation of cold. The impressions are supposed to be caused in both cases by the same force or agent; in the first instance, the impulse passing from the heated iron to the hand; in the second, from the hand to the ice. What the nature or essence of this thing is, which produces such different feelings by moving in opposite directions, and which makes the difference between summer and winter, nobody has yet discovered. It is named *heat.* Some have conjectured it to be a kind of material fluid, exceedingly subtle and ethereal, having no weight, existing diffused throughout all things, and capable of combining with every known species of matter; and this supposed fluid has received the name of *caloric.* Others think heat is not a material thing, but merely *motion:* either waves, or undulations produced in a universal ether, or a very rapid vibration, or trembling of the particles of common matter, which is in some way contagious, and passes from object to object. Of the essential nature of heat we understand nothing, and are acquainted only with its *effects:*—our information is limited to its behavior. It resides in matter, moves through it, and is capable of variously changing its conditions. It is an agent producing the most wonderful results every where around and even within us;—a force of such tremendous energy, such far-reaching, all-pervading influence,—that we may almost venture to say it has been appointed to take control of the material universe;

while in the plan of the Creator, it is so disciplined to the eternal restraints of law, as to become the gentle minister of universal beneficence.

2. **To what Extent the Earth is warmed by the Sun.** Heat comes from the sun to the earth in streams or rays associated with light. It has been ascertained by careful measurement, that the quantity of solar heat which falls upon a square foot of the earth's surface in a year would be sufficient to melt 5400 lbs. weight of ice; and as a cubic foot of ice weighs 54 lbs., the heat thus annually received would melt a column of it 100 feet high, or a shell of ice enveloping our globe 100 feet thick. As the sun turns around once in 25 days, thus constantly exposing different parts, we conclude that equal quantities of heat are thrown from all portions of his surface, and are thus enabled to calculate the total amount of heat which he imparts annually. If there were a sphere of ice 100 feet in thickness completely surrounding the sun, at the same distance from him as the earth's orbit, his heat would be sufficient to melt it in the course of a year. This quantity of heat would melt a shell of ice *enveloping the sun's surface* 38.6 feet thick in a minute, or 10.5 miles in thickness in a year. We are, therefore, warmed by heat-rays shot through a hundred million miles of space, from a vast self-revolving grate having fifteen hundred thousand miles of fire-surface heated seven times hotter than our fiercest blast furnaces.

3. **We get Heat also from the Stars.**—Although the sun is the most obvious and conspicuous source of heat for the earth it is by no means its *sole* source. Of the enormous quantity of heat that streams away in all directions from his surface, the earth receives but a small fraction. But it is neither lost nor wasted; he not only warms the earth, but assists to warm the universe. Our globe catches a trifling portion of his rays; but the rest fly onward to distant regions, where all are finally intercepted by the wandering host of orbs with which the heavens are filled. And what the sun does, all the other stars and planets are also doing. A mighty system of exchanges (32)* is established among the bodies of space, by which each radiates heat to all the rest, and receives it in turn *from* all the rest, according to the measure of its endowments. The whole stellar universe thus contributes to our warmth. It is a startling fact, that if the earth were dependent *alone* upon the sun for heat, it would not get enough to make the existence of animal and vegetable life possible upon its surface.

* These numbers refer to paragraphs.

It results from the researches of Pouillet, that the starry spaces furnish heat enough in the course of a year to melt a crust of ice upon the earth 85 feet thick, almost as much as is supplied by the sun. This may appear strange, when we consider how immeasurably small must be the amount of heat received from any one of these distant bodies. But the surprise vanishes, when we remember that the whole firmament of heaven is so thickly sown with stars, that in some places thousands are crowded together within a space no greater than that occupied by the full moon. (Dr. Lardner.)

4. **Heat unequally Distributed upon the Earth.**—The quantity of heat which the earth receives from the sun is very unequal at different times and places. The earth turns around every day; it is globular in form, and is constantly changing the position of its surface in relation to the sun, as it travels about him in its annual circuit. The consequence is, that we receive more heat during the day than at night; more at the equator than toward the poles; more in summer than in winter. We are all aware that the temperature may fall from blood heat at mid-day, to the point of frost or freezing at night; and while at the equator they have a temperature averaging, the year round, 81-5 degrees, at New York (less than 3,000 miles north), the average annual heat falls to 50 degrees; and at Labrador (less than a thousand miles further north), the average temperature of the year sinks below freezing. Nor do places at the same distance from the equator receive equal amounts of solar heat. A great number of circumstances connected with the surface of the earth, disturb its regular and uniform distribution. Dublin for example, though between eight and nine hundred miles further from the equator than New York, has as high a yearly temperature. Some places also experience greater contrasts than others between the different seasons: thus while New York has the summer of Rome, it has also the winter of Copenhagen.

II.—INFLUENCE OF HEAT UPON THE LIVING WORLD.

5. **It Controls the Distribution of Vegetable Life.**—It is this variable quantity of heat received at different places and seasons, which determines the distribution of life upon the globe. Certain tribes of plants, for example, flourish in the hot regions of the tropics, and cannot live with a diminished intensity of heat. Accordingly, as we pass to the cooler latitudes, they disappear, and new varieties adapted to the new conditions take their place. As we pass into still colder regions, these again give way to others of a hardier nature, or which are capable of

living where there is less heat. As we proceed from the hot equator to the frozen poles, or as we pass upward from the warm valley to the snowy summit of a lofty mountain, we cross successive belts of varying vegetation, which are, as it were, definitely marked off by the different quantities of heat which they receive. "In the tropics we see the palms, which give so striking a characteristic to the forests, the broad-leaved bananas, and the great climbing plants, which throw themselves from stem to stem, like the rigging of a ship. Next follows a zone described as that of evergreen woods, in which the orange and the citron come to perfection. Beyond this, another of deciduous trees—the oak, the chestnut, and the fruit trees with which, in this climate, we are so well acquainted; and here the great climbers of the tropics are replaced by the hop and the ivy. Still further advancing, we pass through a belt of conifers—firs, larches, pines, and other needle-leaved trees—and these, leading through a range of birches, which become more and more stunted, introduce us to a region of mosses and saxifrages, but which at length has neither tree nor shrub; and finally, as the perpetual polar ices are reached, the red snow algae is the last trace of vegetable organization."

6. **Heat Regulates the Distribution of Animals.**—It is the same also with animal life. Different animated races are adapted to different degrees of temperature, and belong within certain heat-limits, just like plants. In going from the equator to the poles, different classes of animals appear and fade away, as the temperature progressively declines. Some are adapted to the alternations of winter and summer by changes of their clothing; and others, as birds, are pursued from region to region by the advancing temperatures. Animals whose constitutions are conformed to one condition of heat, if transported to another, suffer and perish: while the lion is confined to his torrid desert of sand, the polar bear is imprisoned in the frigid desert of ice; and, in both cases, the sunbeam is the chain by which they are bound.

7. **Heat Influences Man's Physical Development.**—Nor does man furnish an exception to these controlling effects of temperature. The striking peculiarities of physical appearance and endowment, exhibited by different tribes and communities of men, is well known; and it has long been understood that much of these differences is due to the all-powerful influence of heat. "The intense cold, dwarfs and deforms the inhabitant of the polar regions. Stunted, squat, large-headed, fish-featured, short-limbed and stiff-jointed, he resembles in many points the wolves and bears in whose skins he wraps himself. As he approaches the sunny south, his stature expands, his limbs acquire shape

and proportion, and his features are ameliorated. In the genial region, he is beheld with that perfect conformation, that freedom of action and intellectual expression, in which grace and beauty consist."

8. **Extremes of Dress in Different Localities.**—The remarkable contrasts of temperature which different races experience, is well illustrated by their circumstances of dress. While in the West Indian Islands a single fold of cotton is often found to be an incumbrance, the Greenlander wraps himself in layer after layer of woollens and furs, fox-skins, sheep-skins, wolf-skins, and bear-skins, until we might suppose him well guarded against the cold; yet with a temperature often a hundred degrees below the freezing-point, he cannot always protect himself against frozen extremities. Dr. KANE observes, "rightly clad, he is a lump of deformity waddling over the ice: unpicturesque, uncouth, and seemingly helpless. It is only when you meet him covered with frost, his face peering from an icy halo, his beard glued with frozen respiration, that you look with intelligent appreciation on his many-coated panoply against king Death."

9. **Temperature and Character.**—The effect of cold is to benumb the body and blunt the sensibility; while warmth opens the avenues of sensation, and increases the susceptibility to external impressions. Thus, the intensity with which the outward world acts upon the inward through the sensory channels, is regulated by temperature. In cold countries the passions are torpid and sluggish, and man is plodding, austere, stolid, and unfeeling. With the barrenness of the earth, there is sterility of thought, poverty of invention, and coldness of fancy. On the other hand, the inhabitants of torrid regions possess feverish sensibilities. They are indolent and effeminate, yet capable of furious action; capricious in taste, often ingenious in device; they are extravagant and wild in imagination, delighting in the gorgeous, the dazzling, and the marvellous. In the medium heat of temperate climates, these marked excesses of character disappear; there is moderation without stupidity, and active enterprise without fierce impetuosity. Society has more freedom and justice, and the individual more constancy and principle: with loftiness of thought, there is also chastening of the imagination. By comparing the effects of climate in the torrid, temperate, and frigid zone, we observe the determining influence of external conditions, not only upon the physical nature of man, but over the mind itself. "We may appeal to individual experience for the enervating effects of hot climates, or to the common understanding of men as to the great control which atmospheric changes exercise, not only over the intellectual powers, but even on our bodily well-

being. It is within a narrow range of climate that great men have been born. In the earth's southern hemisphere, as yet, not one has appeared; and in the northern, they come only within certain parallels of latitude. I am not speaking of that class of men, who in all ages and in every country, have risen to an ephemeral elevation, and have sunk again into their native insignificance so soon as the causes which have forced them from obscurity cease, but of that other class of whom God makes but one in a century, and gives him a power of enchantment over his fellows, so that by a word, or even by a look, he can electrify, and guide, and govern mankind."—(Dr. DRAPER.)

10. **Influence of the Supply of Fuel.**—The abundance or scarcity of the supply of fuel, as it controls the amount of artificial heat, exerts a powerful influence upon the condition of the people in various ways; indeed, it may involve the health and personal comfort of whole nations, to such an extent, as even to contribute to the formation of national character. Where fuel is scarce, houses are small, and their occupants crowded together; the external air is as much as possible excluded; the body becomes dwarfed; and the intellect dull. The diminutive Laplander spends his long and dreary winter in a hut heated by a smoky lamp of putrid oil; an arrangement which afflicts the whole nation with blear eyes. Scarcity of fuel has not been without its effect in forming the manners of the polished Parisians, by transferring to the theatre and the café those attractions, which, in countries where fuel is common and cheap, belong essentially to the domestic hearth.

11. **Temperature and Language.**—ARBUTHNOT suggested not only that heat and air fashion both body and mind, but that they also have a great effect in forming language. He thought the serrated, close way of speaking among the northern nations, was owing to their reluctance to open their mouths wide in cold air, which made their speech abound in consonants. From a contrary cause, the inhabitants of warm climates formed a softer language, and one abounding in vowels. The Greeks, inhaling air of a happy medium, were celebrated for speaking with the wide-open mouth and a sweet-toned, sonorous elocution.

12. **Man may Make his own Climate.**—So controlling is this agent, and yet man comes into the world defenceless from its invasions; provided with no natural means of protection from its disturbing and destructive influence. But in the exercise of that intelligence which gives him command over nature, he has studied the laws, properties, and effects of heat, and the methods by which it may be produced

and regulated. He has devised the means of creating an artificial and portable climate, and thus of releasing himself, in a great measure, from the vicissitudes of temperature. We are to regard the production and control of artificial climate, as an art involving the development and expansion of mind and body, the preservation of health and the prolongation of life. Such has been the thought expended upon this subject, and so important the results to the well-being of man, that we may almost venture to measure the civilization of a people, by the perfection of its plans and contrivances for the management of heat.

III.—MEASUREMENT OF HEAT. THE THERMOMETER.

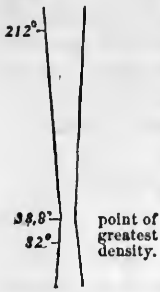
13. **Heat tends to Equal Diffusion.**—We have said that heat is a force, or energy, existing everywhere throughout nature. Every kind of matter which we know contains heat, but all objects do not contain equal quantities of it. If left to follow its own law, heat would distribute itself through all the matter around, until each body received a certain share; and it would then be in a condition of general rest, or equal balance, (*equilibrium.*) It is to this state that heat constantly tends. If a very hot body of any kind is brought into a room, we all know it will at once begin to lose its heat, and that the temperature continues to descend until it is the same as the surrounding air, walls, and furniture.

14. **How do we get acquainted with Heat?**—But before heat can tend to equilibrium, it must first be thrown *out* of this state. There are forces which tend to disturb the *equal balance* of heat, causing it to leave some bodies, and accumulate in others in unusual or excessive quantities. It is the passing of heat from body to body, from place to place,—robbing one substance of it and storing it up in another; in short, its *motion*, and the effects it produces, which enable us to become acquainted with it. How, then, may we know when one substance has been deprived of heat and another has received it? or how can we ascertain the *quantity* of it which a body possesses?

15. **Heat accumulating in Bodies, enlarges them.**—It is an effect of heat, that when it enters into bodies it makes them larger; it increases their bulk, or expands them, so that they occupy more space than they did before. A measure that will hold exactly a gallon in winter, will be expanded by the heat of summer so as to hold more than a gallon. The heat of summer lengthens the foot-rule and yard-stick. A pendulum is longer in summer than in winter, and therefore swings or vibrates slower, which causes the clock to lose time. Twenty-three

pints of water, taken at the freezing point, would expand into twenty-four by being heated to boiling. The difference in the heat of the seasons affects sensibly the bulk of liquors. In the height of summer, spirits will measure five per cent. more than in the depth of winter. (Graham.) When 180 degrees of heat are added to iron, 1000 cubic inches become 1045; 1000 cubic inches of air become 1365. Some substances, however, in *solidifying* expand. This is the case with water, which attains its greatest density, or shrinks into its smallest space, at the temperature of 38·8°, as seen in fig. 1. From this point, either upward or downward, it enlarges; and at freezing, or 32°, the expansion amounts to about $\frac{1}{9}$th of its bulk. Ice therefore floats upon the surface of water. The wisdom of this exception is seen, when we reflect, that if it sank as fast as it is formed, whole bodies of water would be changed to solid ice.

Fig. 1.

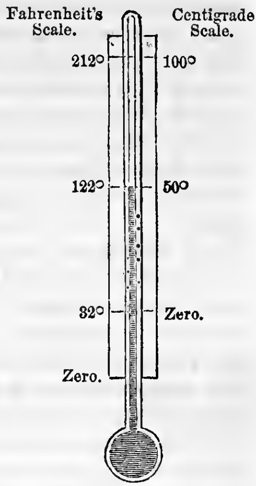


16. **Relation between Heat and Expansion.**—In the same manner, all the objects about us are changed in their dimensions as heat enters or leaves them. Different substances expand differently by the same quantities of heat; but when a certain measured amount is added to, or taken from the same kind of substance, it always swells or shrinks to exactly the same extent. The variation of size produced in solid substances, such as wood, stone, or iron, is very small; we should not be aware of it without careful measurement. The same proportion of heat causes liquids, such as water, alcohol, and mercury, to vary in bulk more than solids; while heat added to gases, or airs, produces a much greater expansion than it does in liquids. Although heat thus causes bodies to occupy more space and become larger, yet it does not make them heavier. The same substance weighs exactly the same, no matter how cold or how hot it is; hence heat is called *imponderable*.

17. **Principle and Construction of the Thermometer.**—If, then, when a substance receives a certain quantity of heat, it undergoes a certain amount of enlargement, we can use that enlargement as a measure of the heat; and this is what is done by the *thermometer* or heat-measurer. A common thermometer is a small glass tube, with a fine aperture or hole through it, like that in a pipe stem, and a hollow bulb on one end of it fig. 2. This bulb and part of the tube is filled with the liquid metal mercury. By suitable means, the air is removed from the empty part of the tube, and its open end sealed up. The bulb is then dipped into water containing ice, and a mark is made

upon the tube at the top of the mercurial column. This point of melting ice is the same as that at which water freezes, and is hence called the *freezing point.* The tube is then removed, and dipped into boiling water. The heat passes from the water, through the glass, into the mercury, which rapidly expands and rises through the narrow bore. It passes up a considerable distance, and then stops; *that* amount of heat will expand it no more. The height of the mercury is again marked upon the tube, and this is called the *boiling point of water.* The distance upon the tube between these two points is then marked off into 180 spaces, which are called *degrees,* and marked (°). Now, it is clear that the amount of heat which runs the mercury up through these 180 spaces is precisely the same quantity that changed the water from the freezing to the boiling point; so that we may say that the water in this case received 180 degrees of heat. If we mix a pound of water at the boiling point with another pound at the freezing point, the result will be a medium; and if the thermometer is plunged into it, the mercury will stand at the ninetieth space—that is, it contains 90 degrees of heat according to this scale of measurement. And so, by dipping the thermometer into any vessel of water, we ascertain how much heat it contains.

Fig. 2.



Thermometer.

18. **How Thermometers are Graduated or Marked.**—But this is not the way that the scale of the common thermometer is actually marked. Its inventor, Fahrenheit, instead of beginning to count his degrees upward from the freezing point, thought it would be better to begin to count from a point of the extremest cold. Accordingly, he mixed salt and snow (55) together, and putting his thermometer in it, the mercury fell quite a distance lower than the freezing point of water. This he supposed to be the greatest cold it is possible to get, though an intensity of cold has since been obtained 150° lower. Marking off this new distance through which the mercury had fallen, in the same way as above, he got 32 additional spaces or degrees. Calling this point of least heat or greatest cold he could get, *nought* or *zero* he counted up to the freezing point of water, which was 32°, and

adding this to the 180 above, he got 212 as the boiling point of water. This is the way we find the common thermometer scale marked (Fig. 2) upon brass plates, to which the glass tube is attached. The *centigrade* thermometer calls the point of melting ice *zero*, and marks the space up to boiling water into 100 degrees. In Reaumur's thermometer, the same space is divided into 80 degrees. Degrees below zero are marked with the minus sign, thus —. It deserves to be remarked, that the glass tube expands by heat as well as the mercury, but by no means to so great a degree. And besides, there being a considerable quantity of mercury in the bulb, it requires but a very small expansion of it to push the quicksilver up the narrow tube, through a perceptible space.

19. **Exactly what the Thermometer indicates.**—The word thermometer is derived from *thermo*, heat, and *metron*, measure, and it therefore signifies heat-measurer. But what does it measure? That which is measured we usually name *quantity*. But we must not suppose that the thermometer indicates quantities of heat in any absolute sense. For example, if we dip a gill of water from a spring in one vessel, and a gallon in another vessel, a thermometer will indicate exactly the same degree of heat in one as in the other; but we cannot thence infer that the absolute quantity of heat is as great in the gill of water as in the gallon. The thermometer shows us simply the *degree of intensity* of the heat in its mercury; and as this constantly tends to the same point as that of surrounding bodies, we take *its* degree to be *their* degree. If the thermometer suspended in a room stands at 70°, we say the room is at 70°, because heat tends to equalization. If by opening windows or doors the thermometer falls to 60°, we say the room has lost 10° of heat,—speaking of it as a measured quantity. The instrument indicates variable degrees of intensity, which are converted into expressions of quantity. We shall shortly see that there are certain conditions of heat which the thermometer totally fails to recognize.

20. **Importance of the Domestic use of the Thermometer.**—As the question of temperature is one of daily and hourly interest, not only of the utmost importance in conducting numerous household operations, but of the highest moment in relation to the maintenance of health, it will at once be seen that a thermometer is indispensable. Every family should have one, and accustom themselves to rely upon it as a practical guide in relation to heat, and not to depend upon *feeling* or *guessing*. Thermometers costing from fifty cents to a dollar and a half, will answer all ordinary purposes. They are so mounted that the scale

and tube may be drawn out of the frame, so that the bulb can be immersed in a liquid, if required. They must be gradually warmed before dipping in hot liquids to prevent fracture of the glass, and of course need to be handled with much care. Their scales extend no higher than the boiling point of water. There is usually some departure from the accurate standard in the indications of the cheaper class of instruments. Mr. TAGLIABUE, a prominent maker of this city, states that these variations rarely exceed from 1 to 2 degrees.

21. **Interesting Facts of Temperature.**—We group together a few points of temperature of familiar interest.*

Best temperature for a room	65°–68°
Lowest temperature of human body (in Asiatic cholera)	67°
Mean temperature at the equator	81°
Heat of the blood	98°
Beef's tallow melts	100°
Mutton tallow melts	106°
Highest temperature of human body (in tetanus or lockjaw)	110°
Stearine melts	111°
Spermaceti melts	112°
Temperature of hot bath	110°–130°
Phosphorus inflames, Friction matches ignite	120°
Tea and coffee usually drank	130°–140°
Butter melts	130°–140°
Coagulation of albumen	145°
Scalding heat	150°
Wax melts	155°
Milk boils	199°
Sulphur melts	226°
Cane sugar melts	320°
Baking temperature of the oven	320°–400°
Sulphur ignites	560°
Heat of the common fire	1000°

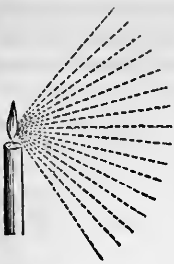
IV. RADIATION OF HEAT AND ITS EFFECTS.

22. **Heat passing through Bodies.**—Heat in motion around us is constantly passing *through* some substance, or from one material body to another. But all substances do not behave alike toward it. They do not all receive, retain, or part with it in the same way. Through certain bodies it passes rapidly in straight lines, like rays of light, and is then termed *radiant* heat, and this kind of heat-motion is called *radiation*, and the substances which allow it to pass through them are said to *transmit* it. We receive radiant heat from the sun and from artificial fires; and the air is one of those substances which permit it to pass through.

* For a further list of temperatures, see Appendix, A.

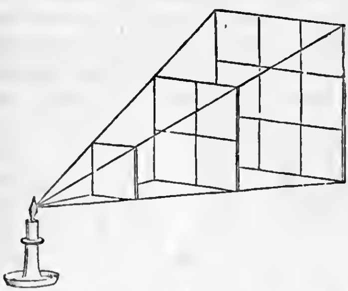
23. **Decrease in the Force of Heat-rays.**—When heat radiates from any source, as the sun, a stove, an open fire, or flame, it passes from each point in all directions Fig. 3; it spreads out or *diverges* as it passes away so as to become weaker and much less intense. It decreases in power at a regular numerical rate, as seen in Fig. 4. It is commonly said that the intensity of radiant heat decreases inversely as the square of the distance; that is, if in standing before the fire at a distance of two feet from it, we receive a certain amount of heat, and then we step back to twice that distance, we shall receive but one fourth the quantity; at thrice the distance, but one ninth; and at four times the distance, but one sixteenth the quantity, as is shown in Fig. 4. But this statement is only true when we consider the heat as passing from a single point. When it flows from an infinite number of adjacent points,—that is, a *surface*, which is the way it is practically emitted, it does not decrease at so rapid a rate.

Fig. 3.



Radiation of heat.

Fig. 4.



Showing the rate at which radiant heat is diffused and weakened.

24. **Different kinds of Heat.**—We all know that some substances will let light pass through them, and others will stop it. It is just so with heat: but the same substances which transmit light, do not always transmit heat. Air allows both to pass without obstruction; but water, which so freely allows the passage of light, has very little power to transmit heat. Rays of light, passing through water, are strained of nearly all their heat. But there seems to be a difference in the source and nature of the heat itself, as to its power of getting through various bodies. Glass allows solar heat to go through it, but not artificial heat. A pane of glass held between the sun and one's face will not protect it from the heat; but it may be used as a fire-screen. If we place a plate of glass and of rock-salt before a hot stove, the dark heat will pass freely through the salt, but not through the glass. The glass is, therefore, *opaque* to heat (if we may borrow the language of light), while salt is *transparent* to it, and is hence called the *glass* of heat.

Meloni has shown that if the quantity of dark, radiant heat transmitted through air, be expressed by 100, the quantity transmitted through an equal thickness of a plate of rock-salt will be 92; flint glass, 67; crown glass, 49; alum, 12; water, 11.

25. **Heat which does not go through is Absorbed.**—When a substance does not permit all the rays of heat which strike upon it, to pass through, those which are detained, or lodged within it, are said to be *absorbed* by it. Thus, fine window-glass transmits only 49 heat rays in a hundred, the remaining 51 being *absorbed* by it. Now it is clear, that if all the heat pass *through* a substance, none can accumulate *in* it to warm or heat it. It is the heat detained or lodged in a body that warms it. The heating power is proportional to absorption. The atmosphere lets the sun's heat all pass—does not absorb it; it is therefore not warmed by it.

26. **Conditions of Radiation.**—The power of a body to emit or radiate heat, depends first, upon the quantity which it contains. Other things being the same, the higher its temperature compared with the surrounding medium, the more rapidly will it throw off its heat. As it cools, the radiation becomes slower and slower. But all subtances at the same temperature, do not throw out their heat alike. The condition of surfaces exerts a powerful control over radiation. Rough, uneven surfaces radiate freely, while smooth, polished surfaces offer a barrier to heat, which greatly hinders its escape. Metals, as their surfaces are capable of the highest polish, are the worst radiators. According to Meloni, surfaces smoked or covered with lampblack, radiate most heat. If the power of radiation of such a surface be represented by 100, that of glass will be 90 (it is therefore an excellent radiator), polished cast-iron, 25; polished wrought iron, 23; polished tin, 14; brass, 7; silver, 3. By tarnishing, or rusting metallic surfaces, their radiating power is increased. Leslie has shown that, compared with a smoke-blacked surface, as 100, clean bright lead is 19, while if tarnished, it is 45. If the actual radiating surface is metallic, it matters little what substance is under it. Glass covered with gold-leaf, is reduced in its radiating power to the condition of a polished metal. If the bright, planished, metallic surface is in any way dulled or roughened, as by scratching or rusting, its power of throwing off heat is greatly increased. Indeed, if the polished surface is only *covered*, the same effect is produced. Rumford took two similar brass cylinders, covered one with a tight investment of linen, and left the other naked· he then filled each with hot water, and found that the same amount of

heat which was thrown off by the covered cylinder in 36½ minutes, required 55 minutes to radiate from the naked cylinder.

27. **How Polishing affects Surfaces.**—Dr. LARDNER says "the diminution of radiating power, which ordinarily accompanies increased polish of surface, is not a consequence of the polish in itself, but of the *increased density of the outer surface*, produced by the act of polishing; and the effect of roughening is to be ascribed to the removal of the outer and denser coating."

28. **Best Mode of Confining and Retaining Heat.**—These principles show us how best to enclose and retain heat when we wish to prevent waste from radiation. Glass, porcelain, and stone ware surfaces, radiate freely: vessels of these materials are not the best to preserve foods and fluids hot at table. They should either be of polished metal, or have bright metallic covers, which will confine the heat. Bright tea-urns and coffee-pots are best to retain their contents hot; and a tea-kettle keeps hot water much more effectually if clean and bright, than if covered with soot, though it is much harder to boil. Pipes intended to convey heat should be bright and smooth, while those designed to radiate or expend it, should be rough. For the same reason, polished stoves and stove-pipes are less useful in warming rooms than those with rougher surfaces.

29. **Color of Surfaces does not influence Radiation.**—It is very generally supposed that the *color* of a substance influences the escape of heat from it. But the experiments of Dr. BACHE have shown that this is a popular fallacy. He has proved that color exerts no control on the radiation of non-luminous heat, or such as is unaccompanied with light. A body will emit heat from a white or black surface with equal facility.

30. **Heat thrown off from Bodies.**—Radiant heat striking upon bodies, if it is not permitted to pass instantly through them in straight lines, is either *absorbed* or *reflected*. If reflected, it is instantaneously thrown back from the surface of the body, and therefore does not enter to warm it. If absorbed, it is gradually taken into the substance, and raises its temperature. A bright metallic surface will reflect the heat rays and itself remain quite cold. As heat cannot get *out* through a bright surface, so it cannot get *in* through it. All the heat that is thrown upon such a body, is either reflected or absorbed; that which is not disposed of one way goes the other. If half of it is absorbed, the other half will be reflected. Glass absorbs 90 per cent. and reflects 10, while polished silver reflects 97 per cent. and absorbs but 3. A good absorbing surface is a bad reflecting surface, and a good reflector is a

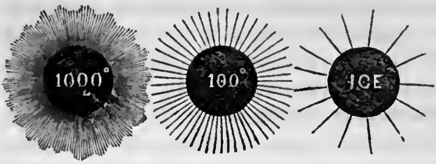
bad absorber. So a good radiating surface absorbs well and reflects badly, while a bad radiating surface absorbs badly but reflects well. The density, or polish of a surface controls the *admission* as well as the *escape* of radiant heat. Two kinds of heat may thus pass in straight lines from a body—radiant heat and reflected heat. The former comes from within, and therefore cools it; the latter strikes against it, and rebounds without either warming or cooling it.

31. **Color of Surface influences the admission of Heat.**—We have seen (29) that color has no influence over radiating surfaces; but the power which bodies possess of *absorbing* heat, depends very much upon color. FRANKLIN spread differently colored pieces of cloth upon snow in the sunshine. That of the black color sunk farthest below the surface; which showed that it melted the most snow, and consequently received most heat. The blue piece sunk to a less depth, the brown still less, and the white hardly at all, which showed that it absorbed least heat. Hence, by scattering soot over snow, its melting may be hastened: it will absorb more of the solar heat. A dark-colored soil warms easier in spring, is earlier, and has a higher temperature during summer, than one in other respects similar but of a lighter color. Darkening a soil in color, therefore, is equivalent to removing it farther south. Grapes, and other fruits, placed against a dark wall, will mature or ripen earlier than if against light-colored walls, because, for the same reason, they are warmer. So, also, in the matter of clothing, white throws off the solar heat, while black absorbs it.

32. **Exchanges of Heat—it escapes from all Substances.**—It has been stated that, down to 200° below the freezing point of water, substances contain heat and may part with it: and as we know of no means by which heat can be absolutely enclosed or confined within bodies, all are regarded as not only *possessing* the power of radiation, but as actually *exercising* it. Rays of heat pass away in every direction, from all points of the surfaces of all bodies. When several objects of various temperatures, some cold and some hot, are placed near each other, their temperatures gradually approach the same degree, and after a time they will be found to have reached it. Now all these bodies are supposed to be constantly radiating heat to each other, and hence constantly *exchanging* it. If we place a cannon-ball at a temperature of 1000° or a red heat, beside another at 100°, it will part with its heat rapidly to the latter, as illustrated by the radiant lines in Fig. 5. But the ball at 100° also radiates its heat, although more slowly, and thus returns a portion to the hotter ball; so that there is an exchange established. But if a ball of ice at 32° be placed beside the cannon-ball at

100°, the same thing takes place, only in a less intense degree; and if an ice-ball from the Arctic region at 100° below the freezing point, were placed beside another at 32°, exactly the same thing would occur. Thus all bodies are constantly interchanging heat and tending to equalization.

Fig. 5.



Exchanges of heat; it radiates from bodies at all temperatures.

33. **Starlight Nights colder than cloudy Ones.**—The various objects upon the earth's surface, are not only continually radiating their heat to each other, but also upward through the air into space. If there be clouds above, they throw it back again to the earth's surface; but if the sky is cloudless, the heat streams away into space, and there is none returned. At night, therefore, when there is no heat coming down from the sun, and no clouds to prevent its escape from the earth, the temperature of the earth's surface and the objects thereon, falls. Those which radiate best, cool fastest, and sink to the lowest temperature. Clear, starlight nights are thus colder than cloudy nights; and although more pleasant and inviting for evening walks, require that more clothing should be worn.

34. **How Dew is Produced.**—The cause of dew was not understood until lately. Many were persuaded that it came out of the earth; while others thought it fell as a fine rain from the elevated regions of the atmosphere. The alchemists regarded it as an exudation from the stars. They believed dew-water contained celestial principles, and tried to obtain gold from it. The problem was solved about forty years ago, by Dr. Wells, who first considered it in connection with the radiation of heat. The air contains moisture in the state of invisible vapor; if its temperature be high, it will hold more moisture, if low, less (286). When, therefore, the air is sufficiently cooled, its moisture is condensed, and appears as drops of water. These are often seen in summer days upon the outside of the pitcher of cold water; improperly called the *sweating of the pitcher*. The moisture that is seen trickling down the window-pane in winter, is condensed from the vapor of the air in the room, by the outward escape of heat from the glass, and the consequent cooling of the air in contact with it inside. When, therefore, by nightly radiation, any objects upon the earth's surface have become so cold as to cool the air in contact with them,

sufficiently to condense its moisture, *dew* is formed, and the degree of temperature at which this effect takes place, is known as the *dew-point.*

35. **Conditions of the Deposit of Dew.**—Every calm and clear night the surface of the ground cools by radiation from 10° to 20°. But this surface is composed of various objects, which radiate unequally. Some part with their heat so rapidly as to cool the air down to the point of condensation, and dew is deposited upon them. Others radiate so slowly that their temperatures do not sink to the dew point, and no dew is formed upon them. Good radiators become covered with dew, while bad radiators remain dry. Grass, for example, is an excellent radiator, and it receives dew copiously, while under the same circumstances, stones, being bad radiators, are not moistened. Dew is deposited from a stratum of air only a few inches thick, which is condensed by contact with the cold body. If, however, that stratum of air *is moved away* before it gets sufficiently cooled, no dew will be formed. Hence, when the air is in motion, as on windy nights, there is no dew. Fall of temperature always precedes the formation of dew, and the greater the fall, the heavier the dews; the quantity of moisture in the atmosphere, in both cases being the same. Farmers very well know that nights with heavy dews are very cold; but the cold is the *cause*, not the *effect*, of the dew. The moister the air is, with the same descent of temperature, the more dew falls. Thus, arid deserts are dewless, notwithstanding the intense nightly radiation.

36. **Exchanges of Heat may prevent Dew.**—We have noticed PREVOST's theory of the exchanges of heat, by which, all bodies are assumed to radiate heat to each other constantly (32). This explains why little or no dew is found under trees. While the grass radiates upward, the foliage radiates downward, and thus checks cooling. For this reason, no dew is precipitated on cloudy nights. As objects radiate upward, the clouds radiate back again, and prevent the falling of the temperature. More dew falls upon the summits of mountains, where objects are most open to the sky, than in valleys, where the angle of radiation or access to the open heavens is much less. Objects protected in any way from exposure to the sky, are, to that extent, guarded from dew.

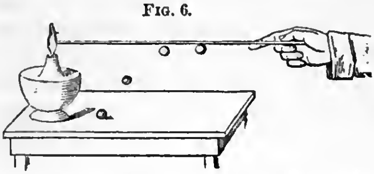
37. **Frost Caused in the same way as Dew.**—As a certain amount of cooling, deposits moisture from the air, more still, freezes it; and hence, *frost* or frozen dew. This extreme cooling is often hurtful to vegetation, and during the serene nights of spring, tender plants are often killed, as is frequently the case with immature fruits and grain of autumn. Here, again, all circumstances which oppose radiation, prevent the cooling. Vegetables, sheltered by trees, suffer less than

those not so protected. A thin covering of cloth or straw, preserves plants, as may also fires that fill the air with smoke.

V. CONDUCTION OF HEAT AND ITS EFFECTS.

38. **Heat creeps slowly through some Bodies.**—If we place one end of a bar of metal in a fire, that end becomes hotter than the other parts of the bar. But this effect is only temporary; the heat will gradually pass through it, being communicated from particle to particle, until the other extremity becomes heated. This is easily shown by taking several marbles, and sticking them to an iron or copper wire with wax Fig. 6. If now heat is applied to one end of the wire, it gradually travels along, the wax is melted, and the marbles drop off successively. The heat in this case is *conducted* by the metal.

Fig. 6.



The balls drop successively as the heat moves along the rod.

39. **Different Substances conduct at different Rates.**—Heat diffuses in this manner, at very unequal speed through different substances. If we hold one end of a nail in a candle flame, it soon gets so hot as to burn the fingers; while we can fuse the end of a glass rod in a lamp, although holding it within an inch of the melting extremity. Iron thus conducts heat much better than glass. Those substances through which heat is diffused most rapidly, are called *good* conductors, while those through which it passes slowly, are *bad* conductors. In general, the denser a body is,—that is, the closer are its particles,—the better does it conduct heat; while the more porous, soft, loose and spongy it is, the lower is its conducting power. The metals, therefore, are the best conductors, while bodies of a fibrous nature, such as hair, wool, feathers, and down, are the worst conductors of heat.

40. **Rumford's Scale of Conductors.**—Rumford arranged bodies in the following order, their conducting power progressively diminishing as the list proceeds. Gold, silver, copper, iron, zinc, tin, lead, glass, marble, porcelain, clay, woods, fat or oil, snow, air, silk, wood-ashes, charcoal, lint, cotton, lampblack, wool, raw silk, fur.

41. **Conducting Power of Building Materials.**—Bad conductors,—*non-conductors*, as they are called,—afford the best barriers to heat, and they are employed when it is desired to confine it. In winter, nature protects the earth and crops from excessive cold, by a layer of non-

conducting snow. The birds, she protects by feathery and downy plumage; quadrupeds, by hair, wool, fur;—and even the trees, by porous, non-conducting bark. In the management of heat, man finds the variation in the conducting powers of bodies, of the highest importance. In building houses, the worst conductors are the best materials for the walls. While they promote warmth in winter, by retaining the heat generated by fires within, they are favorable to coolness in summer, by excluding the external heat. HUTCHINSON examined some building materials, and ascertained their conducting powers to be as follows, omitting fractions. (Slate being taken as 100.) Marble 75 to 58, fire brick 62, stock brick 60, oak wood 34, lath and plaster 25, plaster of Paris 20, plaster and sand 18. The hard woods conduct better than soft, and green woods better than dry. Dry straw, leaves, &c., are good non-conductors, and are used to cover tender plants in winter, but if wetted, they convey heat much better.

42. **Non-conducting properties of Air.**—Air is one of the most perfect non-conductors; RUMFORD thinks it is the best of all. The conducting power of air, however, is greatly increased by moisture. If we represent the power of common dry air to conduct heat, by 80, its power, when loaded with moisture, rises to 230,—it is nearly trebled. For this reason, damp air feels colder to the body—it conducts away its heat faster. Those substances which enclose and contain air, as powdered charcoal, tan-bark, sawdust, chaff, &c., are good non-conductors of heat. Sawdust is an excellent bar to heat; it should not be too much pressed together, as then, the particles, being in too close contact, conduct better:—nor too loose, as the air circulates through it, and thus *conveys* the heat. A layer of air between double windows, checks the escape of heat, but we do not, in such a case, avail ourselves of its perfect non-conducting power, otherwise we might use it to enclose ice-houses, &c. It is easily set in motion (97), and thus becomes a ready transporter of heat. Loose, porous bodies are filled with it, and they act as non-conductors by preventing its motion.

43. **Non-conducting Properties of Clothing.**—Winter apparel is made of non-conducting woollen fabrics, which prevent the escape of heat from the body. Cotton carries off the heat faster than wool; and linen still faster than cotton. Linen is pleasantest in summer to relieve the body of heat, but it cannot defend the system like flannel against the sudden changes of temperature in an inconstant climate. In local inflammation of the body, linen is the best for dressings and applications, as it is a better conductor, and therefore cooler than cot-

ton.* The high non-conducting power of the woollens, is shown by the common practice of preserving ice in hot weather, by simply wrapping it in flannel.

44. **Our Sensations of Heat depend upon Conduction.**—The sense of touch is an unreliable guide to the *degree of* heat, because substances are so diverse in conducting power. The badly conducting carpet feels warmer to the naked feet than the better conducting oilcloth, because the latter will carry away the heat faster from the skin, although both are at exactly the same temperature. This influence of conduction over sensation, as also the remarkable difference of conducting power among solids, liquids, and gases, may be shown in a forcible manner. If the hand be placed upon metal at 120° it will be burned, owing to the rapidity with which the heat enters the flesh. Water will not scald, provided the hand be kept in it without motion, till it reaches the temperature of 150°; while the contact of air at 250° or 300° may be endured. Sir JOSEPH BANKS went into a room, heated to 260°, and remained there a considerable time without inconvenience. The particles of air are so far asunder, that the heat crosses their inter-spaces with difficulty; and as but few of them can come in contact with the body at once, the amount of heat that they can impart is comparatively small.

VI. HEAT CONVEYED BY MOVING MATTER.

45. **It is carried by Particles in Motion.**—The freedom with which the particles of liquids and gases move among each other, is another source of the motion of heat. Water conducts heat but very imperfectly. If a glass tube filled with water, be inclined over a lamp, so that the flame is applied at the upper end Fig. 7, the water will boil at the top of the column, but below the point where the flame is applied, the temperature of the water will be but little elevated in a long time. The *conduction* of heat is not influenced by the *position* of the body along which it passes. It moves through a conductor as swiftly downward as upward, or horizontally. Had the heat, in this case, been *conducted*, it would have travelled as readily down the water column as upward. Yet all understand that

FIG. 7.

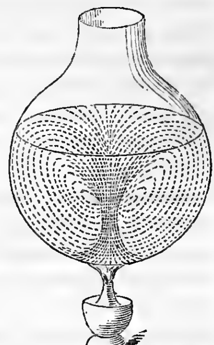
The water does not conduct the heat downwards.

* Linen is also best for dressing local inflammations, because its fibres are round and smooth, and therefore, less irritating. The fibres of cotton are flat and angular, and of woollen, rough and jagged, and consequently, unfit for this purpose (795).

a large amount of water may be heated by a small fire, if the heat be applied at the bottom. The cause of this is, that the lower layer of water in the vessel, being warmed, expands, becomes lighter, and for the same reason that a cork would rise, ascends through the mass of liquid above. Its place is taken by the colder liquid, which in turn warms, expands and ascends; and thus *currents* are formed, by which the heat is conveyed upward, and diffused through the mass. This mode of heat movement is hence called *convection* of heat.

46. **How the Water-currents may be shown.**—The circulation thus produced by ascending and descending currents, may be beautifully seen by nearly filling a pretty large glass flask with water, and dropping into it a few small pieces of solid litmus (*a cheap, blue coloring substance*), which sink through the liquid. On applying heat to the bottom of the vessel by a small lamp, a central current of water, made visible by the blue tint it has acquired from the litmus, is seen rising to the surface of the liquid, when it bends over in every direction like the branches of the palm tree, and forms a number of descending currents, which travel downward near the sides of the vessel Fig. 8. Two causes operate here to distribute the heat. The warm liquid constantly conveys it away, and at the same time, the colder particles are continually brought back to the source of heat, at the bottom. Exactly the same thing takes place when air is heated; it expands, becomes lighter, rises in currents, and carries with it the heat. We shall refer to this principle again, when speaking of the contrivances for warming rooms.

FIG. 8.



Currents produced in water by boiling.

VII. VARIOUS PROPERTIES AND EFFECTS OF HEAT.

47. **Heat added to Solids, liquefies them.**—Not only is the *size* of bodies influenced by heat, but also their *state*, or *form*. As heat enters a solid body, its particles are forced asunder, until at length they lose their cohesive hold of each other, and fall down into the liquid state. The particles have become loosened and detached, and glide freely among each other in all directions. Carbon and pure alumina are the only substances that have not been liquefied by any amount of heat yet applied. Some solids, at a given point of temperature, enter

suddenly into the liquid state, and others pass gradually through an intermediate stage of pastiness or softening.

48. **Melting Points.**—That degree of temperature which is required to melt a substance, is called its melting or fusing point. The common temperature of the air is sufficient to melt some substances. From this point all along up to the highest heat, at which carbon refuses to liquefy, various substances melt at different temperatures, showing that each requires its particular dose of heat to throw it into the liquid state. Thus, mercury is a liquid at common temperatures, and is the only metal that exhibits this peculiarity. Phosphorus melts at 108°, wax 142°, sulphur 226°, sugar cane 320°, tin 442°, lead 612°, zinc 773°, silver 1873°, gold 2016°, iron 2800°. Liquidity seems thus to be produced by the combination of solids with heat. Take the heat from a liquid and it solidifies. Take away the heat from water until it falls to 32°, and it becomes solid water, or *ice*. If kept perfectly still, it may be lowered below 32° before the atoms lock together into the crystalline or congealed state; but if the water is jarred or agitated, crystalline ice results at that temperature. Heat taken from mercury until it falls to 39° below zero, causes it to harden into a solid, ringing metal—*freezes* it. – 180° of heat taken from alcohol, do not freeze, but make it thick and oily. As heat combined with solids produces liquids, so heat combined with liquids produces vapors or gases. Heat added to ice generates water—added to water generates steam. The heat which converts solids into liquids, is called caloric of *fluidity*, and as gases are known as *elastic* fluids, the heat which changes liquids to gases is called *caloric of elasticity*.

49. **What is meant by Specific Heat.**—If we take equal weights of different substances, and expose them to the same sources of heat, they do not all receive it with equal readiness; in the same length of time some will be much more warmed than others. If a lamp flame of a given size will raise the temperature of a pound of spirits of turpentine 50° in ten minutes, it will take *two flames* of the same size to raise a pound of water through the same temperature in the same time, or it will take the same flame twenty minutes, or twice as long. It is clear that the water in this case, in being raised through the same temperature, has received twice as much heat as the spirits of turpentine. If a flame of a certain size will heat a pound of mercury through a certain number of degrees in a certain time, it will take 30 flames of the same heating power, to raise a pound of water through the same range of temperature in the same period; to raise it through the same number of degrees, therefore, water requires thirty times

the heat that mercury does. This would seem to show that different bodies have different capabilities of holding or containing heat, or, as it is usually said, they have different *capacities* for heat: and, as each substance seems to take a peculiar or particular quantity for itself, that quantity is said to be its '*specific*' heat. The specific heat of water is greater than that of any other substance. In ascending from a given lower to a higher point, it takes into itself or swallows up more heat than any other body; and in cooling down through that temperature, as it contains more to impart, so it gives out more heat than any other body. If the specific heat of water is represented by 1000, that of an equal weight of charcoal is 241, sulphur 203, glass 198, iron 113.79, zinc 95.55, copper 95.15, mercury 33.32.

50. **Why Water was made to hold a large amonnt of Heat.**—When we consider the extent to which water is distributed upon the earth, we see the wisdom of the arrangement by which it is made to hold a large amount of heat, and the necessity that it should slowly receive, and tardily surrender what it possesses. Suppose that the water of oceans, lakes, rivers, and that large proportion of it contained in our own bodies, responded to changes of temperature, lost and acquired its heat as promptly as mercury: the thermal variations would be inconceivably more rapid than now, the slightest changes of weather would send their fatal undulations through all living systems, and the inconstant seas would freeze and thaw with the greatest facility. But now the large amount of heat accumulated in bodies of water during summer is given out at a slow and measured rate, the climate is moderated, and the transitions from heat to cold are gradual and regulated.

51. **Why Water is so cooling when drunk.**—It is because water is capable of receiving so much heat, that it is better adapted than any other substance to quench thirst. A small quantity of it will go much further in absorbing the feverish heat of the mouth, and throat, than an equal amount of any other liquid. When swallowed and taken into the stomach, or when poured over the inflamed skin, it is the most grateful and cooling of all substances. For the same reason, a bottle of hot water will keep the feet warm much longer than a hot stone or block.

52. **Concealed or latent Heat.**—All changes in the *densities* of bodies by which their particles are forced into closer union, or to greater distances apart, are invariably accompanied by changes of heat. Caloric is supposed to be contained in bodies, something as water is held in a sponge—lodged in its cavities or pores. If a wet sponge is

compressed, water is squeezed out; but, when it expands again, it will again imbibe the liquid. In like manner material substances, when condensed into less space, give out heat, and, when dilated, they take it in or absorb it. If a piece of cold iron is smartly hammered upon an anvil, its particles are forced closer together, and its heat is driven out of its concealment, the iron becomes hot. By suddenly condensing the air as in the instrument called the fire-syringe, in which a close fitting piston is driven down a tube (Fig. 9), the condensed air gives out so much heat as to set fire to tinder. Now, before condensing the iron, or the air, in these cases, they appeared cold, the thermometer detected in them no heat; yet they contained heat, and condensation brought it out. As we cannot find it by the ordinary test, we infer that it was concealed or *latent* in the iron and air. Heat is capable, therefore, of becoming lost or hidden in bodies, and then of again re-appearing under proper circumstances. We call this *latent* heat, because we must call it something, and the term is convenient; but we are probably very far from a true explanation of the facts in the case.

FIG. 9.

Air condenser.

53. **How much Concealed Heat Water holds.**—Whenever a solid is changed to a liquid, a certain amount of heat disappears—goes into the latent state. If we take a lump of ice at zero, fix a thermometer in it, and expose it to a source of heat, the mercury in the thermometer will be seen to gradually rise up to 32 degrees. It then becomes stationary, although the application of heat is continued. But another change now sets in—the ice begins to melt. While this continues, the thermometer does not rise, and the water at the end of the melting is at exactly the same temperature that the ice was at its commencement. As soon, however, as the ice is all melted, the mercury begins again to ascend, and the water becomes warm. Now, all the heat which entered the ice to liquefy it while the mercury was standing still, went into retirement in the water which was produced—became latent. It is very easy to find out how much heat becomes thus hidden when ice changes to water. If we take an ounce of ice at 32°, and an ounce of water at 174°, and add them together, the ice will melt and we shall have two ounces of water at 32°. The ounce of hot water, therefore, parted with 142° of its heat, which has disappeared in melting the ice. 142° is thus the latent heat of fusion of ice, which is hidden in the resulting water. The quantity of latent heat absorbed by different solids in entering upon the liquid condition

is variable, but a certain amount disappears in all cases. Thus, if a mass of lead be heated to 594°, it will then become stationary, although the addition of heat is continued; but the moment the temperature ceases to rise, it will begin to fuse, and the temperature will continue steadily at 594° until the last particle of lead has been melted, when it will again begin to rise. Those who have attempted to procure hot water from snow for culinary purposes, know by the delay of the result the great loss of heat which is involved. The heat necessary simply to melt 100 pounds of ice, without raising its temperature a single degree, would be sufficient to raise more than 80 pounds of ice-cold water up to boiling.

54. **Beneficial Effects of this Law.**—This law of the latent heat of liquidity, operates admirably to preserve the *forms* of material objects against the effects of fluctuating temperatures. The stability of bodies is too important a circumstance, and their liquefaction too considerable an event, to be made dependent upon transient causes. If, when ice is at 32°, the addition of one degree of heat would raise it to 33°, and thus throw it into the liquid form, all the accumulated snows of winter might be turned almost in an hour into floods of water, by which whole countries would be inundated. But so large a quantity of heat is required to produce this change, that *time* must become an element of the process; the snows are melted gradually in spring, and all evil consequences prevented.

55. **Principle of Artificial Freezing.**—A solid may be changed to a liquid without the direct addition of heat. Attraction or affinity may produce the change. Yet the same amount of heat is required to go into the latent state. Salts have a strong attraction for water. If we put some common salt or saltpetre into water at the common temperature, it will become colder. The salt in dissolving, that is, in assuming the liquid state, must have heat; it therefore takes it from the surrounding water, which, of course, becomes colder. A mixture of five parts sal-ammoniac and five of saltpetre, finely powdered, and put in nineteen parts of water, will sink its temperature from 50° to 10°; that is, 40 degrees. When snow is mixed with a third of its weight of salt, it is quickly melted. The powerful attraction of the salt forces the snow into a liquid state; but it cannot take on this state without robbing surrounding bodies of the heat necessary to its fluidity. Ices for the table are made in summer by mixing together pounded ice and salt, and immersing the cream or other liquid to be frozen (contained in a thin metallic vessel,) into the cold brine, produced by the melting of the ice and salt. A convenient method of freezing a little water

without the use of ice, is to drench powdered sulphate of soda (glauber's salt) with muriatic acid. The salt dissolves to a greater extent in this acid than in water, and the temperature may sink from 50° to zero. The vessel in which the mixture is made, becomes covered with frost; and water in a tube, immersed in it, becomes speedily frozen.

56. **Freezing liberates Heat.**—If the change of a solid to a liquid *absorbs* heat, the change of that liquid back again to the solid state, must liberate it. If the liquefying process swallows up heat, the solidifying process must produce the contrary effect—set it free again. As the thawing of snow and ice in spring, is delayed by the large amount of heat that must be stored away in the forming water, so the freezing processes of autumn are delayed, and the warm season prolonged, by the large quantities of heat that escape into the air by the changing of water to ice. The same principle is made available to prevent the freezing of vegetables, fruits, &c., in cellars during intense cold weather. Pails or tubs of water are introduced, which, in freezing, give out sufficient heat to raise the temperature of the room several degrees. Freezing is thus made a means of warming.

57. **Evaporation of Water.**—Water, at the surface, is constantly changing into invisible vapor, and rising into the air, which is called *evaporation*. It goes on at all temperatures, no matter how cold the water is: indeed, evaporation constantly takes place from the surface of ice and snow. The ice upon the window often passes off as vapor, without taking on the intermediate form of water. Still, the rate of evaporation increases as the temperature rises, so that it proceeds faster from the surface of waters in temperate, than in higher latitudes; and more rapidly still at the equator. Evaporation into the air proceeds more rapidly when the weather is dry, and is checked when it is damp. It is also hastened by a current. Water will evaporate much quicker when the wind blows, than when the atmosphere is still, because, as fast as the air becomes loaded with moisture, it is removed and drier air takes its place. Extent of surface also facilitates evaporation. The same quantity of water will disappear much quicker in shallow pans, than in deep vessels.

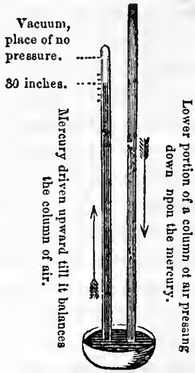
58. **What occurs in Boiling.**—When water is gradually heated in a vessel, minute bubbles may be seen slowly to rise through it. These consist of air, which is diffused through all natural waters, to the extent of about four per cent., and which is partially expelled by heating. As the temperature increases, larger bubbles are formed at the bottom of the vessel, which rise a little way, and are then crushed in and disappear. These bubbles consist of vaporized water, or steam, which is

formed in the hottest part of the vessel; but as they rise through the colder water above, are cooled and condensed. The simmering or singing sound of vessels upon the fire just before boiling, is supposed to be caused by vibratory movements produced in the liquid by the formation and collapse of these vapor bubbles. As the heating continues, these steam globules rise higher and higher, until they reach the surface and escape into the air. This causes that agitation of the liquid which is called boiling or *ebullition.*

59. **Influence of the vessel in Boiling.**—Different liquids boil at different temperatures: but the boiling point of each liquid varies with circumstances. The nature of the vessel has something to do with it, which depends upon its attraction for the water. To glass, and polished metallic surfaces, it adheres with greater force than to vessels of rough surfaces. Before the water can be changed to vapor in boiling, this adhesion must first be overcome. Water upon the surface of oil, boils two degrees below water in a glass vessel, in consequence of the oil having no attraction for the water.

60. **Measuring the Pressure of the Air.**—Air has weight like visible ponderable matter, and presses down upon the surface of water the same as upon the ground. The pressure of the air is measured by a *barometer*, which is simply a glass tube about a yard long, closed at one end, filled with mercury, and then inverted with its open end in a vessel of mercury, as shown in Fig. 10. The liquid metal in the tube, is thus balanced against the air outside, and falls to a point upon the scale, which exactly indicates the pressure of the air. A column of atmosphere from the ground to its upper limit, is about as heavy as a column of mercury 30 inches high. We represent in the figure, but a single column of air pressing down upon the mercury; but we must remember that its surface is completely covered by such columns of air. Of course, the empty space or vacuum in the upper part of the tube permits the mercury to rise and fall without disturbance. From various causes the weight of the atmosphere varies; when it is heavier, it presses harder upon the mercury, and drives it up; when it is lighter, the mercury falls. The ordinary fluctuations of atmospheric pressure, cause the mercury to play along a scale of some two inches. As there is only a

Fig. 10.



Barometer tube.

certain quantity of air to press down upon the earth, in going up a mountain we leave much of it below us: of course, what remains above, is lighter, and presses with less weight. Hence, in ascending a mountain, the mercury in the barometer sinks in proportion as we rise higher.

61. **Influence of Air-pressure upon Boiling.**—It is reported by travellers that, upon high mountains, meat cannot be cooked by the common method of boiling. The reason is, that the boiling water is not hot enough; and the reason of *that* is that the pressure of the air being partially taken off, the water finds less resistance to rising into vapor, and a lower degree of heat produces the effect. The boiling point thus fluctuates with the barometric column: the natural variations of atmospheric pressure, at the same level, make a difference of $4\frac{1}{2}$ degrees in the boiling point of water.

62. **Employment of the Principle in Refining Sugar.**—It is often useful to boil off liquids at low temperatures. In order to change coarse, brown sugar into refined, white sugar, it has to be dissolved and purified. It is then reproduced by evaporating away the water. But the heat of the common boiling point is too great. So the refiner pumps out the air from above the boiling pans, by means of a steam-engine. The pressure is taken off, and the water boils away at a low temperature, leaving the sugar crystals perfect.

63. **Elevation of the Boiling Point.**—If the weight of air pressing upon a liquid affects its boiling point, for the same reason the weight of the liquid *itself*, must affect it. When salts are dissolved in water, they render it heavier, and its boiling point is always raised. Some salts, however, raise it more than others. Water saturated with common salt (100 *water to* 30 *salt*), boils at 224°; saturated with nitrate of potash (100 *water to* 74 *salt*), it boils at 238°; with chloride of calcium, at 264°. Ether boils at 96° (*blood heat*); alcohol, at 174°; turpentine, at 316°; mercury, at 662°. The viscidity of a liquid, or the glutinous coherence of its particles is opposed to its free ebullition.

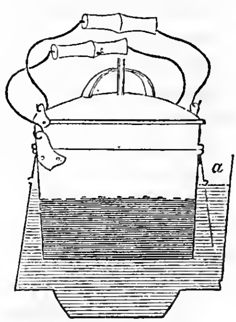
64. **Spheroidal state of Water.**—Water in contact with highly heated metallic surfaces does not boil or vaporize. All may have noticed it dancing or darting about in globules upon a hot stove. The reason offered why a globule does not evaporate from a red-hot surface is, that a stratum of steam is formed under it, which props it up, so that it is not really in contact with the iron; and steam being a nonconductor, cuts off also the heat. Water enters upon the spheroidal state between 288° and 340° of the hot surface: but when the temperature falls, the steam no longer sustains the drop; it is brought into

contact with the iron, and is at once exploded into vapor. This principle is made available in the laundry in judging of the degree of heat. The temperature of the smoothing-iron is determined by its effects upon a drop of saliva let fall upon it. If the drop adheres, wets the iron, and is rapidly vaporized, the temperature is considered low; but if it run along the surface of the metal, it is regarded as sufficiently hot.

65. **But little Heat required to maintain Boiling.**—If a liquid be confined in a sufficiently strong vessel, so that its vapor cannot escape, it may be heated to any desired point of temperature; though at high heats, vapors acquire such an expansive and explosive energy as to burst vessels of the greatest strength. But if the liquid be exposed to the air, it is impossible to raise its temperature above its natural boiling point. All the heat that is added after boiling commences, is carried away by the vapor. The rapidity with which water is raised to the boiling point, depends upon the amount of heat which is made to enter it. But when this point is reached, a comparatively small quantity of heat will maintain it there just as well as more. Water boiling violently, is not a particle hotter than that which boils moderately. When water is brought to the boiling point, the fire may be at once reduced. Attention to this fact would save fuel in many culinary operations.

66. **Double Vessels to Regulate Heat.**—If we have a substance which, placed directly over the fire, would receive an indefinite quantity of heat, but which we desire to raise only to a certain temperature, we place it in a vessel surrounded by another vessel; the outer one being filled with a liquid which boils at the desired temperature. HECKER's farina kettle, Fig. 11, is a culinary contrivance of this kind. The outer vessel is filled with water, while the inner one contains the material to be cooked, which, of course, cannot be heated higher than the boiling point, and is therefore protected from burning. By using any of the salt solutions mentioned (63), higher heats may be communicated to the internal vessel.

FIG. 11.



Section of a culinary bath: *a* opening to introduce water.

67. **Why Puddings, Pies, &c., cool slowly.**—We have seen that water is a bad conductor of heat; that is, heat does not readily pass across its intervening spaces, from particle to particle.

and so become diffused through it. We do not, therefore, heat it by conduction, but by currents produced within it (46), which distribute and commingle the heat throughout its mass. It cools in the same way. As the particles at the surface or sides lose their heat, they fall to the bottom, and others succeed them. If the particles of water could remain stationary, it would be slow and difficult to heat, and equally slow to cool. For this reason soups, puddings, pies, &c., which contain large amounts of hot water, so enclosed and detained in their places that they are not free to circulate, and therefore, are not in a condition to lose their heat, keep hot longer, and cool slower than equal bulks of simple fluids.

68. **Concealed Heat of Vapor.**—As the liquid state is the result of heat combined with solids, the vaporous state is the further result of heat combined with liquids. Enormous amounts of heat are necessary to convert liquids into vapor, but the vapors are no hotter, according to the thermometer, than the liquids were; they are, therefore, reservoirs of insensible heat. All the heat which is necessary to boil off a liquid, becomes *latent* in its vapor. The heat that thus enters the boiling liquid without raising its temperature, must go *somewhere*. It is not sensible in the vapor which ascends from its surface, for that is no hotter than the liquid from which it came. It is contained in the vapor, for it may all be again recovered from it. The quantity of heat which becomes latent in the process of evaporation, is very large. With the same intensity of heat it takes 5½ times as long to evaporate a pound of water, as it does to raise it from freezing to boiling; it therefore receives 5½ times as much heat. If, therefore, 180° were required to boil the pound of water, 1000° are required to change it into a pound of vapor; but, as the pound of vapor is no hotter than the pound of water, 1000° of heat must of course be concealed in it. The latent heat of steam is then 1000°; when condensed, it surrenders that 1000° of heat. The condensation of a pound of steam will raise 5½ pounds of water from the freezing to the boiling point. This fact makes steam a valuable agent for transporting heat, as is done by means of steam pipes for warming buildings (129). Wherever condensed, it liberates large quantities of heat.

69. **Cooling effect of Evaporation.**—Evaporation is therefore a cooling process—it buries or temporarily destroys active heat. For this reason damp soils, although in all other respects like dry ones, are colder. Evaporation dissipates the heat which falls upon them. The heat poured down from the sun in torrid regions would be intolerable,

were it not for the cooling effect of rapid evaporation. Apartments are cooled in hot countries by evaporation, which proceeds from wet curtains. The skin of the body contains millions of little microscopic pores, through which water (*perspiration*) is constantly pouring out to the surface. As it then evaporates into the air and absorbs heat, it becomes a powerful cooling agency and regulator of bodily temperature; while the vapor, which escapes from the breath, exerts a cooling effect within the body. It is very interesting to observe how the great capacity of liquid water for heat, makes it so gratefully cooling as it enters the body; and how its still greater capacity for heat, when passing from the liquid state to the condition of vapor, enables it so constantly to bear away from us the germs of fever as it escapes from the system, in the form of insensible perspiration or vapor. The cooling effect of fanning the face, is partly due to the more rapid removal of the vapor of perspiration from the skin, and partly to the conduction of heat by the particles of moving air. Breezes cool us in the same way. Wet floors become a source of cold, in rooms, through vaporization. The pernicious effect of wearing wet clothing is caused by the rapid evaporation which proceeds from it, thus robbing the body of large quantities of heat. When a person is obliged to remain in wet clothing, evaporation may be stopped by putting on an outer garment, which cuts off the external air.

70. **Reason of "blowing Hot and blowing Cold."**—It was stated that when air or gases are condensed, heat is set free; on the contrary, when they are expanded, their capacity for latent heat is increased, it is absorbed, and cold is produced. This is a main cause of the danger when streams of air reach us through cracks and apertures, although a part of the mischief is caused by conduction. This peril is expressed in the old distich—

> "If cold air reach you through a hole,
> Go make your will and mind your soul."

Air, spouting in upon us in this manner, not only cools by conduction and evaporation, but, having been condensed in its passage through the chink, it expands again, and thus absorbs heat. This is also familiarly illustrated by the process of cooling and warming by the breath. If we wish to *cool* any thing by breathing on it, the air is compressed by forcing it out through a narrow aperture between the lips; as it then rarefies, it takes heat from any thing upon which it strikes. If we desire to *warm* any thing with the breath, as cold hands, for example, we open the mouth and impel upon it the warm air from the lungs without disturbance from compression.

VIII.—PHYSIOLOGICAL EFFECTS OF HEAT.

71. **Local Influence of Heat upon the Body.**—It has been noticed that the general effect of heat upon bodies is to expand them (15). It acts in this way upon the living system, just as upon all other objects. The pleasant sensation of warmth is occasioned by an expansion of the vessels of the skin, and the liquids which they contain; these are rendered less viscid and thick by heat, and made to flow more readily, which produces an agreeable feeling. If the application of heat to a part be continued, the surface becomes red. The diameters of the minute capillary blood-vessels are so expanded, that the red blood-disks are enabled to enter tubes which would not previously admit them. The temperature rises, and there is a slight swelling or increase of the volume of the part, owing partially to the dilatation of the solids and liquids, but chiefly to the presence of an increased quantity of blood. The living tissues at the same time become more relaxed, soft and flexible, and allow rapid perspiration. More heat still produces greater expansion. There is a sense of pain, the organic structure is decomposed, the liquids begin rapidly to dissipate in vapor, and the surface becomes inflamed, blistered, and burned.

72. **General influence of Heat upon the System.**—The body is subject to the action of two kinds of stimulants. *Vital stimulants* are those external conditions, such as air, water, food and warmth, which are necessary to the maintenance of life. *Medicinal* or *alterative stimulants* are those agents or forces which produce temporary excitement within the system, but ultimately depress and exhaust it. Now, in the proportion that is necessary simply to maintain the system at its natural temperature, heat is a healthful, vital stimulant; but beyond this it becomes a disturbing, exhaustive, health-impairing agent. The first effect in undue quantity is excitation; the secondary effect, exhaustion. In the first instance, sensibility is agreeably promoted, voluntary muscular movement assisted, and the mind's action somewhat exalted; but to these effects succeed languor, relaxation, listlessness, indisposition to physical and mental labor, and tendency to sleep. The body possesses a powerful means of self-defence against excessive heat, in the cooling influence of surface evaporation (69), but this power of the system cannot be taxed with impunity. The rush of the circulation to the surface, and the increased transpiration and secretion of the skin, are accompanied by a necessary diminution in the activity of some of the internal organs. As the exhalation from the skin rises, the secretion of the kidneys and mucous membranes falls. The pre-

vailing maladies of hot climates may be referred to, in illustration of the effect of continued heat on the body. Fevers, diarrhœa, dysentery, cholera, and liver diseases, may be regarded as the special maladies of the burning, equatorial regions.—(PEREIRA.)

73. **Consequences of sudden Changes.**—But the worst effect of excessive heat, is not always the immediate stimulation, and consequent exhaustion which it induces; it is the sudden exposure to various degrees of cold which often follows, when the system is in a relaxed and depressed condition, that accomplishes the most serious mischief, laying the train for so many cases of afflicting disease, and premature death. The effect of passing from an over-heated apartment out into a freezing air bath, is suddenly to check the cutaneous circulation, and drive the blood inward upon the vital organs, thus often engendering fatal internal disease. It is thought that a temperature from 60° to 65° is, perhaps, the safest medium at which an apartment should be kept, so that the individual may not suffer from transition to external cold. If this temperature seem uncomfortably low, it is better to increase the apparel than to run up the heat, and risk the consequences of subsequent exposure.

IX. ARTIFICIAL HEAT—PROPERTIES OF FUEL.

74. Artificial heat may be produced in various ways, but the common method is by *combustion*, which is a chemical operation carried on in the air. All the heat which we generate for household purposes, is caused by the chemical action of air upon fuel. But what part of the air takes effect? The main bulk of the air is composed of two elementary gases, *oxygen* and *nitrogen*. In every five gallons of air, there are 4 of nitrogen and 1 of oxygen, mixed and diffused through each other (281). Nitrogen, when separated, proves to have no active qualities; it cannot carry on combustion,—it puts out fire. Oxygen, on the contrary, when separated, proves to be endowed with wonderful chemical energy. A fire kindled in it, burns with unnatural violence; its chemical powers constitute the active force of the air. The nitrogen dilutes and weakens it, thus restraining its activity.

75. **Composition of Fuel,—Office of Carbon.**—The fuel upon which oxygen of the air takes effect in the burning process, consists of various kinds of wood and coal. These are chiefly composed of three elements—oxygen, hydrogen, and carbon, in various proportions. The oxygen they contain, contributes nothing to their value as fuel; *that*

depends upon the other elements: hence, the more oxygen, the less there can be of these other substances, and, of course, the poorer the fuel. Carbon exists largely in all woods and coals. Oxygen and hydrogen, when in their free state,—that is, uncombined, are always gases; they never appear as liquids or solids, and no one has yet been able to force them into these states. Carbon, on the other hand, is an unyielding solid. No chemist has ever yet been able to prepare either *liquid* carbon or *gaseous* carbon. At the intensest white heat, where nearly every other substance melts, or dissipates into vapor, carbon remains fixed. It is the solidifying element of fuel, and it is this property which makes our fires stationary.

76. **Hydrogen, and its Office in Fuel.**—Hydrogen gas, the other element of fuel, when set free is the lightest substance known, being 14 times lighter than air. It is of so light and volatile a nature, that it will combine with solid carbon, and even iron, and carry them up with it into the gaseous state. When combined with fuel, it is condensed down into a solid state, but in the act of burning, it is released, and escapes into the gaseous form. It therefore *burns in motion*, and it is this which produces *flame*. In all ordinary combustion, the flame is caused by the burning hydrogen, and the larger the quantity of this substance in fuel, the greater the flame it will yield when burnt.

77. **Why it is necessary to kindle a Fire.**—Now, for these two substances, oxygen has powerful attractions, and combines with them, producing combustion and heat. Yet atmospheric oxygen is every where in contact with all kinds of fuel without setting them on fire. Why is this? Because the natural attractions of these substances are so graduated, that they do not come into active play at low temperatures. If carbon combined with oxygen at common temperatures, with the same readiness and force that phosphorus does, wood and coal would be ignited like a match, at the slightest friction, and combustive processes would be ungovernable. But as man, all over the world, civilized and savage, is designed to develope and manage fire through the agency of these substances, their energies have been wisely restrained within the limits of universal safety. This makes it necessary to resort to some means, as friction or percussion, to generate heat necessary to *start combustion*, or kindle the fire.

78. **Products of Combustion.**—When the combustive process has commenced, two things take place; the fuel disappears, and the air is changed. The substance of fuel is not destroyed, it only changes its shape, takes on the invisible form, and mounts into the air. Oxygen combines with carbon, both elements disappear, and a new product

results—carbonic acid gas (293). As carbonic acid is thus given off every where by combustion, it is a constant and universal constituent of the atmosphere. It forms 1–2000th of the air, and would increase in quantity, but it is constantly withdrawn by plants. When pure, it extinguishes fire, and when mingled with the air it rapidly diminishes its power of sustaining combustion. When oxygen combines with the hydrogen of fuel, it produces vapor of water, which rises with the carbonic acid and disperses through the air.

79. **Fuel is changed before it is burned.**—In burning, oxygen does not combine directly with hydrogen and carbon, changing them at once to water and carbonic acid. The heat of combustion first decomposes the fuel and re-combines its atoms, forming various compounds under different circumstances, and it is with *these* that oxygen unites. They consist mainly of hydrogen and carbon, and are more abundant as the proportion of hydrogen in the fuel increases. It is rare that these products, thus distilled out of fuel in the burning process, are completely consumed by oxygen; a portion of them escapes, constituting smoke.

80. **Heating powers of Hydrogen and Carbon.**—The proportion of carbon in fuel is always very much greater than that of hydrogen, but the amount of heat which they give out is not in proportion to their relative weights. A given weight of hydrogen, when burned, will produce three times as much heat as the same weight of carbon. A pound of charcoal, which is nearly pure carbon, in burning, produced sufficient heat to change 75 pounds of water from freezing to boiling; while a pound of hydrogen yielded heat enough in burning, to change 236.4 pounds through the same number of degrees. The heat is in proportion to the oxygen consumed; the pound of hydrogen united with 8 pounds of oxygen; while a pound of carbon took but $2\frac{2}{3}$ pounds of it. The heating power of fuel thus depends upon chemical composition, but it is also influenced by other circumstances.

81. **How Moisture affects the Value of Wood.**—When wood is newly cut, it contains a large quantity of water (*sap*), varying in different varieties, from 20 to 50 per cent. Trees contain more water in those seasons when the flow of sap is active, than when growth is suspended; and soft woods contain more than hard. Exposed to air a year, wood becomes *air dried*, and parts with about half its water; 15 per cent. more may be expelled by artificial heat; but before it loses the last of its moisture, it begins to decompose, or char. The presence of water in wood diminishes its value as fuel in two ways; it hinders and delays the combustive process, and wastes heat by evaporation.

Suppose that 100 pounds of wood contain 30 of water, they have then but 70 of true combustive material. When burned, 1 pound of the wood will be expended in raising the temperature of the water to the boiling point, and 6 more in converting it into vapor; making a loss of 7 pounds of real wood, or $\frac{1}{10}$ of the combustive force. Besides this dead loss of 10 per cent. of fuel, the water present is an annoyance by hindering free and rapid combustion.

82. **Heating Value of different kinds of Wood.**—Equal *weights* of different varieties of wood in similar conditions, produce equal quantities of heat; but it will not do to purchase wood by weight, on account of the varying quantity of its moisture. It is sold by measure; but equal measures or bulks of wood do *not* yield equal amounts of heat. According to the careful experiments of Mr. Marcus Bull, the relative heating values of equal bulks (*cords*) of several American woods, are expressed as follows;—shell-bark hickory being taken as 100.

Shell-bark Hickory	100	Yellow Oak	60
Pignut Hickory	95	Hard Maple	60
White Oak	81	White Elm	58
White Ash	77	Red Cedar	56
Dogwood	75	Wild Cherry	55
Scrub Oak	73	Yellow Pine	54
Witch Hazel	72	Soft Maple	54
Apple tree	70	Chestnut	52
Red Oak	69	Yellow Poplar	52
White Beech	65	Butternut	51
Black Walnut	65	White Birch	48
Black Birch	63	White Pine	42

83. **Soft and Hard Woods.**—Some woods are softer and lighter than others, the harder and heavier having their fibres more densely packed together. But the same species of wood may vary in density, according to the conditions of its growth. Those woods which grow in forests, or in rich, wet grounds, are less consolidated than such as stand exposed in the open fields, or grow slowly upon dry, barren soils.

84. **Why Soft and Hard Woods burn differently.**—There are two stages in the burning of wood: in the first, heat comes chiefly from flame; in the second, from red-hot coals. Soft woods are much more active in the first stage than hard; and hard woods more active in the second stage than soft. The soft woods burn with a voluminous flame, and leave but little coal; while the hard woods produce less flame, and yield a larger mass of coal. The cause of this is partly, that the soft woods, being loose and spongy, admit the air more freely, but it is chiefly owing to differences in chemical composition. Pure

woody fibre, or lignin, from all kinds of wood, has exactly the same composition; a compound atom of it containing 12 atoms of carbon, 10 of hydrogen, and 10 of oxygen—or there is just enough oxygen in it to combine with all its hydrogen and change it to water in burning. But in ordinary wood, the fibre is impure; that is, associated with other substances which practically alter its composition. The hard woods are nearest in composition, to pure lignin, but the softer woods contain an excess of hydrogen. For this reason, they burn with more vehemence at first; more carbon is taken up by the hydrogen, in producing flame and smoke, and the residue of coal is diminished. The common opinion, that soft wood yields less heat than hard (*equal weights*) is an error; it burns quicker, but it gives out an intenser heat in less time, and is consequently better adapted to those uses where a rapid and concentrated heating effect is required.

85. **Charcoal as Fuel.**—Charcoal is the part that remains, when wood has been slowly burned in pits or close vessels, with but a limited supply of air, so that all its volatile or gaseous elements are expelled. Wood yields from 15 to 25 per cent. of its weight of charcoal; the more the process is hastened, the less the product. When newly made, charcoal burns without flame, but it soon absorbs a considerable portion of moisture from the air, which it condenses within its pores. When this is burned, a portion of the water is decomposed, hydrogen is set free, and there is produced a small amount of flame. Being very light and porous, and its vacancies being filled with condensed oxygen, (811) it ignites readily, and consumes rapidly. Wood charcoal produces a larger amount of heat than equal weights of any other fuel.

86. **Mineral Coal as Fuel—Anthracite.**—The pit coal which is dug from beds in the earth, is a kind of mineral charcoal. It gives evidence of having been derived from an ancient vegetation, which was by some unknown means buried in the earth, and there slowly charred. Indeed, the properties of the different varieties of coal, depend upon the degree to which this charring operation has been carried. In *anthracite*, which is the densest and stoniest of all, it has reached its last stage; the volatile substances are nearly all expelled, so that nothing remains but pure carbon with a trace of sulphur, and the incombustible ash. From its great density, when we attempt to kindle it, instead of promptly taking fire, the heat is rapidly conducted away, so that the whole mass has to be raised together to the point of ignition. When once thoroughly fired, this coal burns with an intense heat for a long time, though less freely in a grate than in a stove. It is difficult in the grate to keep the whole mass of coal in a state of vivid redness, as the

air conveys away so much heat from the surface of the fire as to coo. it down below the point of combustion (114). Anthracite burns without flame, smoke, or soot, although with sulphurous vapors, which, when the draught is imperfect, or when burned in a stove, are liable to accumulate in the room, to the serious detriment of its inmates. The anthracite fire is objected to by many as causing headache, and other bad symptoms. Aside from its sulphurous emanations, the extreme intensity of its heat, undoubtedly, has a share in producing these effects.

87. **Combustion of Bituminous Coal.**—When the great natural process of underground charring is less advanced, the coals are *bituminous*; that is, they contain bitumen or pitch, a substance rich in hydrogen. These ignite readily, and burn with much flame and smoke. Those which contain the largest proportion of pitchy material, are known as 'fat' bituminous coal, and in burning, they soften or melt down into a cake, (*caking coal*) and stop the draught of air. Those with less hydrogenous matter, are termed 'dry,' or 'semi-bituminous' coal; they burn freely without cementing or caking. Bituminous coals furnish illuminating gas by distillation in iron retorts; a process of charring with entire exclusion of air. The residue left after charring bituminous coal, is called coke; it is procured of the gas manufacturers and used as fuel, burning quietly like anthracite, though, owing to its sponginess, it is more easily kindled and yields less heat. Good bituminous coal burns freely and pleasantly in an open fire, with an agreeable, white flame, producing carbonic acid in large quantity, a small proportion of sulphurous vapor, and the common carbonaceous constituents of smoke (103). Its heat is much less violent than that of anthracite.

88. **Lignite or Brown Coal** is that variety which seems to have been least charred, and still retains the woody structure; its combustive value is low.

89. **Heating Effects of the different Fuels.**—The heating value of these fuels, when burned under the same circumstances, have been determined as follows: One pound of wood charcoal will raise from the freezing to the boiling point, 73 pounds of water. One pound of mineral coal will heat 60 pounds of water through the same number of degrees; and one pound of dry wood, 35 pounds of water in the same way. These are the highest results obtained by careful experiments. In practice, we do not get so great a heating effect; and besides, the circumstances under which the fuel is burned, whether it be in a stove or fire-place, makes considerable difference in the result.

90. **Amount of Air required to consume Fuel.**—As the weight of air

necessary to burn fuel is vastly greater than the fuel itself, and as air is exceedingly light, it will be seen that immense bulks of it are consumed in combustion. It requires 11.46 pounds of air to burn one pound of charcoal; and as one pound of air occupies nearly 13 cubic feet of space, the pound of charcoal will require about 150 cubic feet of air. One pound of mineral coal is burned by 9.26 pounds of air, or 120 cubic feet; and one pound of dry wood consumes 5.96 pounds, or 75 cubic feet of air. These are the smallest possible amounts that can be made to effect the combustion; as fuel is usually burned, much more is consumed.

91. **Too much Air hinders Combustion.**—Yet if the object is simply to *produce heat*, the contrivances we employ should be adapted to admit the least possible quantity of air beyond what actively carries forward the combustion. Excess of air becomes detrimental to the burning process, by conveying away heat which it does not generate, cooling the fuel, and checking the rate of combustion. Indeed, so much air may be projected upon a fire, as to cool it down below the burning point, and thus put it out as effectually as water (114).

X.–AIR CURRENTS—ACTION AND MANAGEMENT OF CHIMNEYS.

92. **Cause of the Chimney Draught.**—The candle flame tends upward; its hot gases and the surrounding heated air rising in a vertical stream, which illustrates the universal tendency of warmed air. No matter how it is heated, it expands, because rarer and lighter, and is pressed upward by that which surrounds it. Not that heated air has any mysterious tendency to ascend, but there being less of it in the same space, the earth does not attract it downward with the same force that it does the denser and colder surrounding air. As the atmospheric particles move among each other with the most perfect freedom, the colder and heavier air takes the lower position, to which gravitation entitles it, and thus drives the warmer air upward. This upward tendency of rarified gases is the force made use of to supply our fires with the large amount of air which they demand. The fire is kindled at the bottom of a tube of iron or brick-work, called a *flue* or *chimney*. The atmospheric column within it is heated and rarified, and the outer air drives in to displace it. This, in its turn, is also heated and ascends; a continuous current is established, and a stream of fresh air secured to maintain the combustion. The chimney also serves to remove from the apartment the noisome and poisonous products of combustion.

93. **Conditions of the Force of Draught.**—The force of the chimney

draught depends upon the velocity of the rising current, and *that* again upon the difference of weight between the column of air in the chimney, and one of equal size outside of it. Three circumstances influence the force of draught: the temperature, length, and size of the air column within the chimney. The hotter it is, the higher it is, and the larger it is, within certain limits, the greater will be its ascensional force. All high chimney stacks, with large channels, containing highly rarified air, produce roaring draughts; while if they be short and narrow, and their temperature low, the draught is proportionally enfeebled. Friction against the sides of the chimney, especially if it be small, operates powerfully to retard the draught. If the chimney be contracted at the bottom, the velocity of the entering air will be increased. If it be narrowed at top, the smoke and hot air will be discharged above with more force, and hence be less likely to be driven down by slight changes in the direction of the wind; yet contractions in the diameter of the chimney at any point, diminish the total amount of air passing through. In practice, chimney-draughts are influenced by several other circumstances, and are frequently so interrupted, that they refuse to carry off the products of combustion, and are then said to *smoke*. Yet these general statements require qualification. A chimney may be so high that the loss of heat through its walls shall cool the current down to a point of equilibrium with the outer air; the draught of a high chimney shaft has been greatly augmented by enclosing it in an outer case to prevent radiation. Nor is the current of air that passes through a chimney, strictly in proportion to the degree of its heat. The draught, at first, increases very rapidly with the temperature, but gradually diminishing, it becomes constant between 480° and 570°, beyond which it diminishes, and at 1800° it is less than at 212°. The reason of this is found in the great expansion of air at a high temperature, by which its volume is so much increased, that, although the velocity may be very great, *the quantity*, when reduced to the temperature of the atmosphere, is less than at a lower temperature.—WYMAN.

94. **Winds cause Chimneys to Smoke.**—A high building, or a tree standing close to a chimney and overtopping it, often disturbs its draught. The wind passing over these objects, falls down like water over a dam, and stops the ascending current so that smoke is forced back into the room; or the wind may strike against the higher object, and, rebounding, form eddies, and thus beat down the smoke. When chimneys are not thus commanded by eminences in the vicinity, gusts of air may still interfere with their draught. To prevent this, they

are often mounted with *turncaps*, *cowls*, or *ejectors* (354) which are so constructed that the effect of the passing wind is to draw off the air from the chimney, forming a partial vacuum into which the gases and smoke rush from below, and so establish an upward current.

95. **New and Damp Chimneys.**—When chimneys are new, the brick and mortar being damp, are good conductors of heat, and take it rapidly from the rising current of warm air. This condenses it, obstructs its ascent, and if the fire below be very hot, the chimney smokes. As it becomes dry, however, and is gradually covered with non-conducting soot, this source of difficulty is removed.

96. **Cold Exposures—Descending Draughts.**—Chimneys in the north end of a house, exposed to cold winds, often draw much less perfectly than those on other sides, or in the still more favorable warm interior of a building. The air in a chimney in the north or shaded side of a house is liable to cool in summer, so as to have a *downward*, draught when not used. If the temperature of the chimney be nearly the same as that of the outer air during the day, the external cooling at night may also create a descending current. When, therefore, the smoke from the neighboring chimneys passes over the tops of those that are drawing downwards, it is sucked in with the current and fills the room below.

97. **Currents counteracting each other.**—We have seen that it is only when the atmosphere is of a perfectly uniform temperature that it is perfectly still; the slightest inequality in its degree of heat, throws it promptly into movement. We are apt to forget the exceeding delicacy with which the different portions of air are balanced against each other. This may be easily shown. If two tubes of unequal height be united by a third (Fig 13), the candle in the longer tube will overcome that in the shorter, and create a downward current in the latter; or if two tubes of equal length, united by a third, as in Fig. 14, have a candle in each, one is soon overcome by the other; and this may happen, even when an opening is made in the third tube, admitting a limited supply of air. It is sometimes attempted to make a current proceeding from a fire, traverse two flues, which join again before discharging their smoke into the air. But this is difficult, if not impossible; for though currents may be commenced in both routes, one quickly neutralizes the other, and but a single flue is used.

FIG. 13.

FIG. 14.

98. **One Chimney overpowering another.**—When there are two fire-places in a room, or in rooms communicating by open doors, a fire in the one may burn very well by itself; but, if we attempt to light fires in both, the rooms are filled with smoke. The stronger burning fire draws upon the shaft of the weaker for a supply of air, and of course brings the smoke down with it. This difficulty may be remedied by opening a door or window, so as to supply both fires with the necessary air. The same effect may take place, even though the two rooms be separated by a partition, when they communicate *atmospherically* by the joints and doors. Sometimes, where the windows are tight, a strong kitchen fire may overpower all the other chimneys in the house and cause them to smoke.

99. **Upper and lower Flues.**—A current entering a chimney through a flue *horizontally*, may interrupt its draught; in all cases of flues entering chimneys, they should be so arranged that the smoke may assume an upward direction corresponding to the course of the main current. There is great danger of smoke when the flue of an upper room is turned into the chimney of a lower room. If a fire is kindled in an upper room when there is none below, the cold air in the main shaft rises, and, mixing with the warm air, dilutes it, and thus checks or obstructs the ascent; while if the lower fire only be kindled, the cold air from the upper flue will rush into the shaft, and cooling it down at that point, may cause the smoke to descend into both rooms. The remedy is, either to keep a fire in both fire-places or to close one with a fireboard.

100. **Admission of too much Air.**—Too large openings in fire-places often occasion smoke by admitting so much air from the room as to cool the upward current, and thus impair its ascensional force. If the fire-place be too high or capacious, or its throat too large, the air is drawn from a large space, or it may pass round behind the fire by way of the jambs on both sides; the current is thus impeded, and the flame, which should be drawn backward, rises directly against the mantel-bar and escapes into the room. The fire-place should be so constructed as to compel all the air which enters it, to pass through or close to the fire.

101. **Admission of too little Air.**—It is well known that a smoky chimney is often relieved by opening a window or outer door; where this is the case, the difficulty is a deficiency of air to supply the

draught. Want of a copious and regular supply of air is by far the most common cause of smoky chimneys. However well constructed and arranged may be the flues and fire-places, if they are not supplied with a proper amount of air they will inevitably smoke. Of course if the room be nearly air-tight, there is no air to supply a current, and there will be no current, for as much air as escapes through the chimney must be constantly furnished from some other source. In such a case, the smoke not being carried off will diffuse through the room. There may even be a double current in the chimney, one upwards from the fire and another from the top downwards, as shown in Fig. 15; these two currents meeting just above the fire, part of the smoke is driven into the room. To ascertain the quantity needed to be brought in under these circumstances, Dr. FRANKLIN'S plan was to set the door open until the fire burned properly, then gradually close it until again smoke began to appear. He then opened it a little wider, until the necessary supply was admitted. Suppose now the opening to be half an inch wide, and the door 8 feet high, the air-way will be 48 square inches, equal to an orifice 6 inches by 8. The introduction of this air is to be in some way effected, the question being where the opening shall be made. It has been proposed to cut a crevice in the upper part of the window-frame; and, to prevent the cold air from falling down in a cataract upon the heads of the inmates, a thin shelf is to be placed below it, sloping upwards, which would direct the air toward the ceiling. The modes of introducing air will be noticed in another place (351).

FIG. 15.

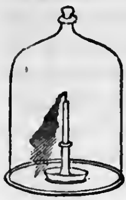
Double current in chimney causing smoke.

102. **Draughts through a Room.**—Currents of air through a room, as from door to door, or window to window, when open, may counteract the chimney draught; or a door in the same side of the room with the chimney may, when suddenly opened or shut, whisk a current across the fire-place, to be followed by a puff of smoke into the room.

103. **Visible Elements of Smoke.**—Smoke consists of all the dust and visible particles of the fuel which escape unburnt, and which are so minute as to be carried upward by ascending currents of air. It is chiefly unconsumed carbon in a state of impalpable fineness, which is deposited as soot along the flue, or, swept upward by the air current, is carried to a greater or lesser height, and finally falls again to the

earth. Thus all that is visible of smoke is really heavier than air which may be shown by placing a lighted candle in the receiver of an air-pump. By then exhausting the air, the flame is extinguished; and the stream of smoke that continues to pour from the wick, falls on the pump-plate, as is seen in Fig. 16, because there is no air to support it. Often, in days when the weather is said to be 'close' we notice that the smoke floats away from the chimney-top and falls instead of rising; so that the air, even within the zone of breathing, becomes charged with the sooty particles. The atmosphere is so rare and light that it cannot sustain the heavy smoke. The common impression that the air on these occasions is *heavy*, which prevents smoke from rising, is quite erroneous. The visibility of smoke is not entirely due to sooty exhalations. Watery vapor is a large product of combustion, and, when the air is warm and dry, it remains dissolved and invisible; but, when it is cold or saturated with moisture, it will absorb no more, and that which rises from the chimney appears as a vapor-cloud, and thus adds greatly to the apparent bulk of the smoke.

FIG. 16.



104. **Other constituents of Smoke.**—Smoke contains many substances beside the carbonaceous dust, which vary with the conditions of combustion and the kind of fuel used. Coal smoke is alkaline from the presence in it of ammoniacal compounds, while wood-smoke is acidulous from the ligneous acids it contains. The smarting sensation produced by wood-smoke in the eyes, is due to the highly irritating and poisonous vapor of *creosote* formed in the burning process.

XI.—APPARATUS OF WARMING.

105. The various devices for warming are to be considered in a twofold relation, as generating heat and affecting the breathing qualities of the air. These topics are often treated together; but, as we desire to present the subject of air and breathing with the utmost distinctness, a separate part will be assigned to it, and the heating contrivances will then be reconsidered in respect of their atmospheric influences.

106. **How Rooms lose Heat.**—Apartments lose their heat at a rate proportional to the excess of their temperature above the external air; the higher the heat, the more rapidly it passes away. Large quantities of heat escape through the thin glass windows. The window panes both *radiate* the heat outward, and it is conducted away

by the external air. Glass is a bad conductor of heat, yet the plates used are so thin as to oppose but a very slight barrier to its escape; on the other hand, it is an excellent absorber and radiator,—so that, in fact, it permits the escape of heat almost as readily as plates of iron of equal thickness. The loss of heat in winter, by single windows, is enormous. Three-fourths or 75 per cent. of the heat which escapes through the glass, would be saved by double windows, whether of two sashes or of double panes only half an inch apart in the same sash. Heat is also lost by leakage of warm rarefied air through crevices and imperfect joinings of windows and doors, while cold air rushes in to supply its place. Heat also escapes through walls, floors, and ceilings, at a rate proportioned to the conducting power of the substances of which they are composed. Another source of loss is from ventilation where that is attended to, whether it be by the chimney, or through apparatus made on purpose, and it may be estimated as about 4 cubic feet of air per minute for each person. This is the lowest estimate; authorities differ upon the point, the ablest putting it much higher (325). The loss from this source is proportional to the scale adopted. Much heat, besides, is conveyed away by the currents necessary to maintain combustion. To renew the heat thus rapidly lost in these various ways, different arrangements have been resorted to, which will now be noticed.

107. **Our Bodies help to Warm the Rooms.**—In estimating the sources of heat in apartments, we must not overlook that generated in our own systems. The heat lost by the body in radiation, is gained to the apartment; in the case of an individual, the amount is small; but where numbers are collected, the effect is considerable. In experiments made upon this point, by enclosing different individuals successively in a box lined with non-conducting cotton, open above and below, and suspended in the air, it was found first, that there is a current ascending from the person on all sides; and second, that the air was found, on an average, 4° higher above the head than below the feet. In a dense crowd, air admitted slowly through the floor at 60°, rises to 70° or 80° before reaching the head. The temperature of a lecture room 9 feet high, and 34 by 23 square, occupied by 67 persons, and the outer air at 32°, rose by the escape of bodily heat during the lecture, twelve degrees.

108. **Ancient Method of Warming.**—The chimney is a modern device, coming into use only 500 or 600 years ago, with the mariner's compass, the printing press, mineral coal, and that array of capital inventions and discoveries which appeared with the daybreak of the new civili-

zation that succeeded the dark ages. Previously to that time, houses were heated as Iceland huts are now,—by an open fire in the middle of the apartment, the smoke escaping by the door, or passing out through apertures in the roof, made for this purpose. The Greeks and Romans had advanced no further than this in the domestic management of heat. They kept fires in open pans called *braziers*. Those of the Romans were elegant bronze tripods, supported by carved images with a round dish above for the fire. A small vase below contained perfumes, odorous gums, and aromatic spices, which were used to mask the disagreeable odor of the combustive products. The portion of the walls most exposed were painted black, to prevent the visible effects of smoke; and the rooms occupied in winter had plain cornices and no carved work or mouldings, so that the soot might be easily cleared away.

1.—OPEN FIRE-PLACES.

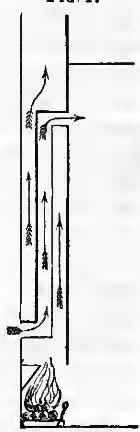
109. **Structure and Improvements.**—With the chimney came the fire-place, which is an opening on one side of its base. At first it was an immense recess with square side-walls (*jambs*) and large enough to contain several persons, who were provided with seats inside the jambs. These fire-places were enormously wasteful of fuel, and were in other respects very imperfect. They have been gradually improved in various ways. By reducing their dimensions and greatly contracting the throat, the force of draught is increased and the liability to smoke diminished. By lowering the mantle or breast, the flow of large masses of air which entered the chimney without taking part in the combustion, was stopped; while, by bringing the back of the fire-place forward, the fire was advanced to a more favorable position for heating the room. Rays of heat, like those of light, when they strike on an object, are reflected at the same angle as that at which they fall,—that is, the "angle of incidence is equal to the angle of reflection." Now, when the jambs were placed at right angles with the back, that is, facing each other, they threw their heat by reflection (and when hot by radiation) backward and forward to each other across the fire. By arranging the jambs at an angle, they disperse the heat through the room. Count Rumford states that the proper angle for the positions of jambs is 135 degrees with the back of the fire-place.

110. **How the open Fire-place warms the Room.**—The heat of combustion from the open fire is entirely radiant—thrown off directly from the burning fuel, or reflected from the sides and back of the fire-

place. It strikes upon the walls, ceiling, floor, and furniture of the room; a portion of it is reflected in various directions, and the rest is absorbed. The objects which receive it are warmed, and gradually impart their heat to the air in contact with them;—gentle currents are thus produced, which help to equalize the temperature of the room. Those portions of the air which are in contact with the fire, become heated by *conduction*, but they immediately rise into the chimney, and are, therefore, of no use in heating the room. As a fire-place is situated at the side of the apartment, and as radiant heat passing from its source decreases rapidly in intensity (23), it is obvious that the room will be very unequally heated. Near the fire it will be hot, while the remote places will be in the opposite condition. There is a semicircular line around the fire-place, in which persons must sit to be comfortable, within which line they are too hot, and beyond which they are too cold. Of course, in this method of warming, the body receives the excess of heat only upon one side at once.

111. **The open Fire not Economical.**———Fuel gives out its heat in two ways, by radiation and by immediate contact. PECLET has shown, by ingenious experiments, that the *radiated* heat from wood was $\frac{1}{4}$; from charcoal and hard coal about $\frac{1}{2}$, of the whole amount produced. As a general result, those combustibles which burnt with the least flame yielded the most radiant heat. As the radiant heat is thus the smaller quantity, the arrangements in which it *alone* is employed are by no means economical; yet the open fire-place heats entirely by radiation, and is therefore the most wasteful of all the arrangements for heating. It is said that in the earlier fire-places 7-8ths, and RUMFORD says 15-16ths of all the heat generated, ascended the chimney and was lost. It is probable that in the best constructed fire-place, from 1-2 to 3-4ths of all the heat is thus wasted. The fire-place is greatly improved in economy and heating efficiency by so constructing it that it may supply a current of heated air to the room. This is done in numerous ways, as by setting up a soap-stone fire-place within the ordinary one, and leaving a vacant space between them, into which cold air is admitted from without, which is then thrown into the room through an opening or register above. This is an excellent plan; it is executed with various modifications, but, if well done, it answers admirably. Even a flue made of some thin

FIG. 17



Air from without warmed by the fire-place.

material, and contained in the chimney, the lower extremity communicating with the external air, and the upper with the room (Fig. 17), answers a most useful purpose. Heat is saved; abundance of air is furnished to the room without unpleasant draughts, while a common cause of smoke is avoided (101).

112. **Franklin Stove.**—Dr. FRANKLIN contrived a heating apparatus of cast iron, which he called the *Pennsylvania fire-place*, but which is generally known as the *Franklin stove.* It offers one of the best methods of managing an open fire. It is set up within the room, and the hot air and smoke from the fuel, instead of escaping from the fire directly up the chimney, is made to traverse a narrow and circuitous smoke flue, which gives out its heat like a stove-pipe; at the same time air is introduced from out of doors through air-passages which surround and intersect the smoke-flue, and, after being warmed, it is discharged into the room by means of proper openings. This apparatus warms, not only by radiation from the burning fuel like the common fire-place, but also by radiation from the hot iron; besides, the air of the room is heated by contact with the metallic plates, and there is still another source of warmth in the hot air brought in from without.

113. **Coal Grates.**—As coal contains more combustible matter in the same space than wood, and produces a more intense heat, a much smaller fire-place answers for it. A very narrow throat in the chimney is sufficient to carry off the smoke. The coal-grate is a more economical contrivance for warming than the larger wood fire-place, chiefly because it lessens the current of air which enters the flue. In the wood fire-place a copious stream of warm air passes up the chimney, which takes no part in combustion, but carries off with it much heat, the place of the escaping warm air being supplied by cold air from without. The coal-grate is closed, like the fire-place, on three sides, the front consisting of metallic bars or grates, which, while they confine the coal, suffer the heat to radiate between them into the room. The sides and back of the grate should be formed of fire-brick, soap-stone, or some slowly-conducting substance, and not of iron, which conducts away the heat so fast as to deaden the combustion—for a fire may be effectually extinguished by contact of a good conducting solid body. For this reason, as RUMFORD first pointed out, there should be as little metal about a grate as possible, the bars being made as slender and as wide apart as practicable, so as to intercept the fewest radiations from the burning surface.

114. **Conditions of Combustion in the Grate.**—The form of the grate

should be such as to expose the largest surface of incandescent coal to the apartment. If it has a circular front, there will be not only more surface, but the heat may then be radiated in all directions; yet, if too great a surface is exposed to air, in extreme cold weather it carries off the heat faster than combustion renews it; and the coal, if it be anthracite, grows black upon the exposed side and burns feebly. The art of burning fuel to the best advantage in open grates, is to maintain the whole mass in a state of bright incandescence, by preventing all unnecessary obstruction of heat, either by contact of surrounding metal, or currents of cold air flowing over the fire. It is very difficult, however, to expose a large fire-surface to the atmosphere, and at the same time properly regulate the quantity of air admitted. It is possible for fuel to smoulder away and entirely disappear with the production of very little sensible heat. To be burned with economy, therefore, it must be burned rapidly under the most favorable conditions of vivid combustion. The heat absorbed by the fuel, the surrounding solids, or the rising vapor, is of course not available, but only the *excess* which is emitted into the room. To cause this lively and perfect combustion, all the air which comes in contact with the fuel must be decomposed and part with the *whole* of its oxygen. Every particle of air passing up through the fire, which does not help the combustion, hinders it, first by carrying off a portion of the heat, and second by cooling the ignited surface so that it attracts the oxygen with less vehemence, and thus causes the fire to languish. The air should also be pure, that is, as little as possible mingled with the gaseous products of combustion. Air entering below a fire, rapidly loses its oxygen and becomes contaminated with carbonic acid; both changes unfitting it for carrying on the process actively in the upper regions of the fire. If, therefore, the mass of burning material is too deep, the upper portions burn feebly and at least advantage; yet if the pieces of coal be large, scarcely any depth of fuel will be sufficient to intercept and decompose the cold air which rises through the wide spaces. If the coal be not large, perhaps a depth of four or five inches will be found most economical.

115. **Different kinds of Grate**—The modifications and variations of the fire-place and coal-grate are innumerable: and the multiplied devices which are continually pressed upon public attention, are, many of them, but reproductions of old plans. The use of a simple iron plate for a fire-back, has been employed to warm an adjoining room situated behind the fire-place. For the same purpose grates have been hung upon pivots, so as to revolve, and thus warm two rooms, as library

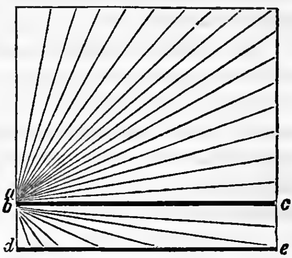
and bedroom alternately. In GOLSON's stove-grate, the fire is contained in an urn or vase-shaped grating, and is surrounded by a circular reflector which throws the rays, both of heat and light, into the room in parallel lines. Coal-grates are also constructed on the principle of the double fire-place, by which warmed air is introduced into the room from without. Dr. FRANKLIN devised an ingenious grate called the *circular fire-cage.* It was so hung as to allow it to revolve. The coal was ignited, as usual, at the bottom, and when the combustion was well advanced, the cage was turned over so as to bring the fire at the top By this means, the fresh coals at the bottom were gradually ignited, and their *smoke* having to pass through the fire above them, was entirely consumed.

116. **Arnott's new Grate.**—Dr. ARNOTT has recently constructed a new grate, in which the same benefit—the *consumption* of smoke, is secured. The bottom of the grate is a movable piston, which may be made to fall a considerable distance below the lower grate bar. A large charge of coals is then introduced, which rests upon the piston and fills the grate. They are lighted at the top, so that the heat passes downward and consumes the smoke as it is formed below. As the coals waste away at the top, the piston may be raised by the poker used as a bar, and thus fresh coal is supplied to the fire *from beneath.* When the first charge is consumed and the piston is raised to the bottom of the grate, a broad, flat shovel is pushed in upon the piston which supports the burning coals, and affords a temporary support for the fire. The piston is then let down to the bottom of the box, and a new charge of coal shot in. This arrangement is valuable for abating the smoke nuisance where bituminous coal is burned. Much ingenuity has been spent upon contrivances to burn or consume smoke. The thing however is impracticable. When smoke is *once produced* by fire, we can no more *advantageously* convert it to heating purposes than we can the smoke of a badly burning candle to the purposes of lighting. When smoke escapes from the ill-adjusted flame of a lamp, we notice that the flame itself is dull and murky, with diminished light; but if it burn without smoke, the flame is white and clear. But we do not say in this case, the lamp *burns its smoke*, but that it *burns without smoke.* The aim should be, so to conduct the first combustion that smoke shall be *prevented.*

117. **Grates should not be set too low.**—As the open fire warms by radiation, it should be so placed as to favor this mode of diffusing heat. The tendency of currents of heated air to rise, secures sufficiently the warmth of the upper portion of the room, so that the main object of

the grate should be to heat the floor. If the fire is situated very low, the radiation will be considerable upon the hearth, while but few heat-rays will strike further back upon the floor. They will pass nearly parallel along the carpet or floor, just as the solar rays, at sunrise, dart along the surface of the earth. If, however, the fire be raised, its downward radiations strike upon the floor and carpet at some distance back, with sufficient force to warm them, just as the sun's rays are more powerful when he shines from a considerable distance above the horizon. If *a* in (fig. 18), represent a radiating point or fire in a room, and *b c* the floor, it will be seen that no heat-rays fall upon it; while if the floor be at *d e*, it will receive rays from the fire. "In such arrangement it is seen by where the ray-lines intersect this floor, that much of the heat of the fire must spread over it, and chiefly between the middle of the room and the grate, where the feet of the persons forming the fireside circle are placed. Striking proof of the facts here set forth, is obtained by laying thermometers on the floors of rooms with low fires, and with similar rooms with fires as usual of old, at a height of about 15 or 16 inches above the hearths. The temperature in the upper parts of all these being the same, the carpets in the rooms with low fires are colder by several degrees than in the others."

FIG. 18.



2.—STOVES.

118. **How Rooms are warmed by Stoves.**—The stove is an enclosure, with us, commonly of iron, so tightly constructed as to admit through an aperture or damper, only sufficient air to maintain the combustion of the fuel, which may be either wood or coal. The heat generated within is communicated, first to the metal, and then by that to the apartment. It is usually situated quite within the room, the products of burning being conveyed away by a flue or pipe. The stove imparts its heat by radiation in all directions; it also heats the air in contact with it, which immediately rises to the upper part of the room, that which is cooler taking its place in the same manner as heat is distributed through water in boiling (46).

119. **Brick, Earthenware, and Porcelain Stoves.**—Stoves made of these

materials are most common in Germany and Russia. They are generally made to project into the room from one side, like a chest of drawers or a sideboard; the door for the fire being sometimes in an adjoining apartment. These stoves heat more slowly, and consequently give out their warmth for a longer time than those made of iron, which are subject to rapid variations of temperature.

120. **Self-regulating Stoves.**—These are stoves to which are appended contrivances for regulating the draught. The principle employed is the expansion of bodies by heat, and their contraction by cold. A bar of brass or copper is so attached to the stove, that when the heat within increases, it lengthens; it then moves a lever and closes the aperture which admits the draught. This checks the fire, and causes the bar slowly to cool; it now contracts, and again opens the aperture of draught. Dr. ARNOTT produced the same result by means of a column of air contained within a tube acting upon mercury which moved a valve, and thus controlled the air-aperture. As the addition and subtraction of heat cause gases to change their bulk more readily than solids, a well constructed regulator of this kind would be more sensitive and prompt in action than one of metal.

121. **Air-tight Stoves.**—The so called *air-tight* stoves are very common. They are designed to admit the air in small and regulated quantities, so as to produce a slow and protracted combustion. This mode of generating heat is less economical than is generally supposed. To become most perfectly available, heat must be set free at certain rates of speed. The compounds formed by combustion at a low temperature, generate much less heat than those which result from quick burning. Indeed, in the low, smothered combustion, the fuel undergoes a kind of *dry distillation*, producing carburetted hydrogen gases which escape into the chimney as unburnt volatile fuel, and are of course lost. These gases are inflammable, and when mixed with air, often cause explosions in air-tight stoves. Dr. URE found that while 3½ pounds of coke evaporated 4½ pounds of water, from a copper pan, when burned in a *single hour*, yet that when the same amount was burned in *twelve hours*, but little over half that quantity of water was evaporated. As has been previously stated, to evolve the largest amount of heat from fuel it must be burned rapidly, and with a supply of air sufficient to carry the oxidation at once to its highest point, by the production of carbonic acid and water. Where the fuel is quickly and completely burned, and the hot, escaping gases are made to traverse a sufficient length of pipe to have parted with nearly all their heat before entering the chimney, there remains noth-

ing to be desired on the score of economy. It is evident that all the heat has been retained in the room, and in this case the stove becomes the most efficient heating apparatus.

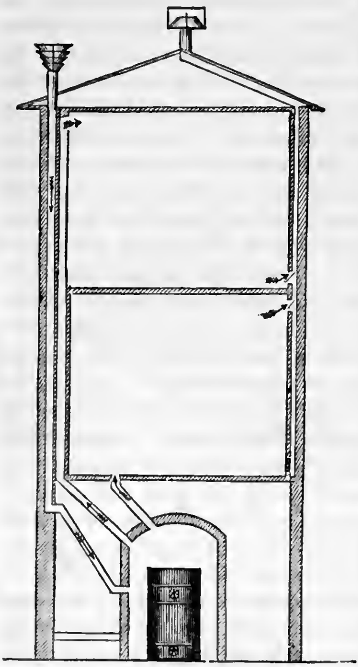
122. **Effect of Elbows in Stovepipes.**—The heating action of the sheet-iron flue or stovepipe, is derived from the hot current of air within it. In proportion therefore as it contributes to the warmth of the room, this current of escaping air is cooled. That this cooling of air within the pipe takes place rapidly, may be shown by the difference of temperature at its connection with the stove, and where it enters the chimney. The cooling takes place of course from without inwards; the outer stratum of the hot air current which is in contact with the pipe cools faster than the interior portion, so that the centre of the current is the hottest. Now it is well known that the effect of elbow-joints in a pipe, is to make the same length of it much more efficacious in warming a room, than it would be if straight. The cause of this is, that the heated air, in making abrupt turns, strikes against the sides with sufficient force to break up and invert its previous arrangement, and so mingle it, that the hotter air from the interior of the current is brought more into contact with the sides of the pipe, and more heat is thus imparted. It also checks the rapidity of the current. As radiation proceeds much slower at low temperatures than at high ones, the pipe, as it recedes from the stove, becomes rapidly less and less useful as a means of diffusing heat into the apartment; it gives out less heat, in *proportion to what it contains*, than the hotter parts of the pipe. There will, therefore, be little gained by greatly lengthening it.

123. **Best qualities of a Stove.**—The desirable points to be secured in the construction and management of stoves, are, *first*, ready contrivances for regulating the draught; *second*, accurate fitting in the joinings, doors, dampers, and valves, to prevent the leakage of foul gases into the room; *third*, enclosure of the fire-space, with slow conductors, as fire-brick or stone; *fourth*, a high temperature, attained by the rapid and perfect combustion of the fuel; and *fifth*, to bring all the heated products of the combustion in contact with the *largest possible absorbing and radiating metallic surface*, so that the iron in contact with the air may not be overheated, but give out its warmth at a low temperature. Large stoves, moderately heated, are therefore most desirable. The cooler the surface of the stove, or the nearer it is in temperature to the air of the room, the more agreeable and salubrious will be its influence. This desirable result is to be obtained only by exposing the greatest quantity of heating surface to the least quantity of fuel—a condition almost reversed in our modern stoves.

3. HOT-AIR ARRANGEMENTS.

124. **Hot-air Furnaces.**—Heating by *hot air*, as it is termed, has recently come into very general use. In this case the heater is not situated in the apartments to be warmed; hot air being conveyed from it through air-flues to the rooms (fig. 19). The most common plan is a hot-air furnace. It is constructed of iron, and usually lined with fire-brick for burning anthracite, and has a flue connecting it with the chimney, to remove smoke. It is enclosed in a case of iron or brick-work, with an interval of space between, forming an air-chamber. Air is introduced into this chamber, either directly from the room, or by means of a conduit, from without the building. The furnace is situated in the cellar or basement, and the entering air heated to the required temperature, by contact with the hot iron, escapes upward from the air-chamber through tin tubes, which distribute it to all parts of the dwelling. It enters the room through apertures called *registers*, which may be opened or closed at pleasure. This method is commended by its economy of space, the heating machine being excluded from the occupied apartments; fuel is also consumed more completely, and with better economy, in a single furnace, than if burned in several stoves or grates. A disadvantage however, is, that the power of the furnace being gauged by the requirements of a certain sized building, or number of apartments, it is not easily accommodated to a fluctuating demand for heat.

Fig. 19.



Manner of warming by Hot-Air Furnaces.

125. **Diffusion of Hot Air through the Apartment.**—There are serious

disadvantages attending the entrance of hot air in large streams through registers in the floor. If it be very hot, it will ascend directly to the ceiling, without imparting its heat to bodies around. In a church, heated by two large hot-air stoves, delivering the air through two large openings in the floor, we have found a difference, after the heating process has been going on three hours, of more than 20° between the temperature near the ceiling and that of the floor. In some public buildings, a stratum of air has been observed at the height of 20 or 30 feet from the floor, with a temperature above that of boiling water, while below it has been disagreeably cool. In private houses, with the hot-air furnaces, now in general use, air is usually introduced at a high temperature. It rises directly to the ceiling, spreads out upon it, and on reaching the walls, descends by them and the windows, more rapidly by the latter (337), until it reaches the floor, along which it is diffused toward the register, when a part is again drawn into the ascending current. Hence we see that those assembling just *around* the register, and not over it, are in the *coldest* part of the room. That this is the case, we have also proved by the thermometer; while the air, midway between the floor and ceiling, in a moderate-sized sitting-room, was at 74°, that near the register, was but 68°.—(WYMAN.) Even in a room heated by a stove, or any other apparatus placed within it, and upon the floor, the air is found, after a time, to arrange itself in horizontal layers, the temperatures of which decrease from above downwards. In an experiment to ascertain the temperature in a room 21 feet high, the following indications were obtained.

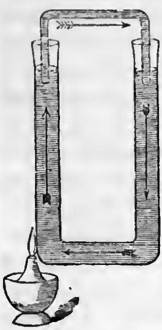
Level of floor,	65°	10. 5	80°
2. 1 foot,	67°	12. 6	81°
4. 2 "	70°	14. 7	86°
6. 3 "	72°	16. 8	90°
8. 4 "	75°	19.	94°

126. **How we are warmed in Hot-air Rooms.**—We are to remember that after all, it is less the contact of heated air which warms us in hot-air apartments, than other agencies. We may enter a room in which the atmosphere is at 70°, or even higher, and yet be *chilly*. Great amounts of air contain but little heat. The quantity of heat that will raise 1 cubic foot of water 1 degree, would be so diffused as to raise 2,850 cubic feet of air one degree.—(ARNOTT.) From the amount of air that comes in contact with our bodies, therefore, we cannot get sufficient heat to warm us rapidly. If the walls, floors, and furniture of the room are cold, though the air be warm, the individual radiates heat to them, and is compensated by none in return; while if they are

warm, they become constant sources of radiant warmth. Hot air may also become a direct source of cold if it be dry. If we moisten the bulb of a thermometer, and expose it to the rays of a fire, it receives the heat and rises; but when moistened and exposed to the action of warm, dry air, it will sink down several degrees, caused by the evaporation which carries off heat. In the same manner, over-dry air may promote cooling by increasing bodily evaporation. We shall refer to the effects of hot air again.

127. **Heating by Hot Water.**—We have seen how water is put in motion by heat; the accompanying figure shows the working of the principle. As the lamp heats the water on one side of the tube, it expands and ascends, the colder water coming forward from below to take its place, which establishes a circulation. As the hot water passes round the circuit, it gradually parts with its heat through the tube to the surrounding air. The great specific heat of water (49) by which it holds a large quantity of caloric, adapts it well for the transportation of this agent; and, as it parts with its large portion of heat but slowly, it is the most constant and equable of all sources of warmth. We have already referred to the significant fact that when the heat of a cubic foot of water is imparted to air, whatever be the number of degrees through which the water falls, it will raise through the same number of degrees 2,850 cubic feet of air.

Fig. 20.



Circulation of water.

128. **Two forms of Hot Water apparatus.**—There are two methods of warming houses by hot water. In one the mechanism is placed in the cellar or basement, and heats air which is conveyed upward to warm the apartments above, as in the case of furnaces. In this form of the mechanism, the pipes do not ascend to any considerable height above the boiler; but, in the other plan, a system of small tubes is distributed through the house, being laid along to fit any form and succession of rooms and passages, or they are coiled into heaps in various situations, and impart their heat by direct radiation. There is a difference in the degree of heat in these two plans. Water exposed to fire, as we have seen, rises in temperature to the boiling point and goes no higher, but this varies with depth and pressure. In those arrangements, therefore, which are confined below, the water hardly rises above the temperature of 212°; while, in those which extend through the dwelling, it ascends many degrees higher. A

good hot-water arrangement, from its constancy and regularity of action, and when not heated above 200° or 212°, affords one of the most agreeable modes of heating a dwelling, although it is at present so expensive as to place it beyond popular reach.

129. **Steam Apparatus for Warming.**—As steam contains a large amount of heat (68), it becomes an available means of its transmission. If admitted into any vessel not so hot as itself, it is rapidly condensed, and at the same time gives its heat to the vessel, which may then diffuse it in the space around. A system of tubes ascending from a boiler may be so arranged as to warm the air which is thrown into the room through a register, or they may be wound into coils as in the previous case (128), and dispense their heat by radiation. The pipes are so placed, that the water from the condensed steam flows back to the boiler, or the hot water may be drawn off into vessels which are made to contribute to the heating effect. This mode of heating requires a temperature always at 212° for the formation of steam, and often much higher to drive forward the condensed water and clear the pipes. A serious drawback to this mode of heating is that the apparatus often emits a disagreeable rattling or clacking sound, owing to the condensation within the pipes and the sudden movements of steam and water. There is also a fundamental objection to the method of warming rooms by heat radiated from coils of pipes, whether they be heated by steam or hot water. In respect of the condition of the air, this is the worst of all methods of heating, for it makes no provision whatever for exchange of air. All the other heating arrangements involve more or less necessary ventilation, but radiating pipes afford none at all.

130. **Risk of Fire by these methods of Warming.**—It has been supposed that the employment of hot water, hot air, and steam pipes, as a means of heating buildings, cuts off the common sources of danger from fires, and is entirely safe. This is a serious error. Iron pipes liable to be heated to 400°, are often placed in close contact with floors skirting boards and wooden supports, which a much lower degree of heat may suffice to ignite. By the long-continued application of heat, not much above that of boiling water, wood becomes so baked and charred that it may take fire without the application of a light. A considerable time may be required to produce this change, so that a fire may actually be "*kindling upon a man's premises for years.*" The circular rim supporting a still which was used in the preparation of some medicament that required a temperature of only 300°, was found to have charred a circle at least a quarter of an inch

deep in the wood beneath it in less than six months. There are numerous cases of buildings fired by these forms of heating apparatus.

131. **Origin of Fires.**—The Secretary of a London Fire Insurance office stated that the introduction of lucifer matches caused them an annual loss of $50,000. Of 127 fires caused by matches, 80 were produced by their going off from heat; children playing with them, 45; rat gnawing matches, 1; jackdaw playing with them, 1. Wax matches are run away with by rats and mice, taken into their holes and ignited by gnawing. These facts point to the indispensableness of match-safes. In London, during a period of nine years, the proportion of fires regularly increased from 1.96, at 9 o'clock, A. M., the time at which all households might be considered to be about, to 3.44 at 1 o'clock, P. M; 3.55 at 5 P. M., and 8.15 at 10 P. M., which is just at the time that fires are left to themselves.

132. **Benefits and Drawbacks of the various methods of Heating.**—Each plan of warming presents its special claims to attention, and vaunts its peculiar benefits. Modifications of every scheme are numerous, and still multiplying. As a result of this inventive activity, there is a gradual but certain improvement. The aim of inventors has hitherto been mainly to secure economical results; a laudable purpose, if not pursued at the sacrifice of health. As people generally become better informed respecting the principles and laws which influence the comfort and well-being of daily life, improvements will be demanded in this direction also. Meantime, each method is to be accepted with its imperfections, though we are not to forget that in their working results much must depend upon proper and judicious management. We recapitulate and contrast the chief advantages and disadvantages of the various methods of heating. Some of the points referred to, particularly those which relate to ventilation, have not been previously noticed, and will be considered when speaking of air.

ADVANTAGES OF OPEN FIRE-PLACES.	DISADVANTAGES OF OPEN FIRE-PLACES.
They promote ventilation—afford a cheerful fireside influence—warm objects, without disturbing the condition of the air—and may furnish warm air from without.	They are uncleanly—require frequent attention—are not economical—are apt to strain the eyes—heat apartments unequally—are liable to smoke.
ADVANTAGES OF STOVES.	**DISADVANTAGES OF STOVES.**
They cost but little—are portable—are quickly heated—and consume fuel economically	They afford no ventilation—if not of heavy metal-plates, they quickly lose their heat—yield fluctuating temperatures—are liable to overheat the air—are liable to leakage of gases—and are not cleanly.

ADVANTAGES OF HOT-AIR FURNACES.

They are out of the way and save space—are cleanly—give but little trouble—may afford abundant ventilation—need waste but little heat—and warm the whole house.

DISADVANTAGES OF HOT-AIR FURNACES.

They are liable to scorch the air—cannot be easily adapted to heat more or less space—are liable to leakage of foul gases—and they dry and parch the air if copious moisture is not supplied.

ADVANTAGES OF HOT-WATER APPARATUS.

They do not burn or scorch the air—give excellent ventilation—do not waste heat—and they warm the whole house. These remarks do not apply to those which heat rooms by radiation from coils of pipe (129).

DISADVANTAGES OF HOT-WATER APPARATUS.

They are expensive in first cost—if adapted for an average range of temperature, they may fail in extreme cold weather (as may also furnaces)—and may give a dry and parched air if moisture be not supplied.

PART SECOND

LIGHT.

I. NATURE OF LIGHT—LAW OF ITS DIFFUSION.

182. **How the outward and inward Worlds Communicate.**—We sit at the window, and have report of the world without. That intelligent consciousness which has residence in the chambers of the brain, holds intimate communion with the external universe, by means of a compound system of telegraphing and daguerreotyping, as much superior in perfection to the devices of art, as the works of the Most High transcend the achievements of man. We lift the curtains of vision, and a thousand objects, at a thousand distances, of numberless forms and clad in all the colors of beauty, are instantaneously signalled to the conscious agent within. Each point of all visible surfaces darts tidings of its existence and place, so that millions upon millions of despatches which no man can number, enter the eye each moment. A landscape of many square leagues sends the mysterious emanation, which, entering the camera-box of the eye, daguerreotypes itself upon the retina with the fidelity of the Infinite. Fresh chemicals are brought every instant, by the little arteries, to preserve the sensitiveness of the nerve-plate, while those that have been used and spent, are promptly conveyed away by the veins. As impressions are thus continuously formed, they are transmitted, perhaps by a true electric agency, along the line of the optic nerve, to be registered in the brain, and placed in charge of memory. By the magic play of these wonderful agents and mechanisms, the world without is translated within, and the thinking and knowing faculty is brought, as it were, into immediate contact with the boundless universe. Let us inquire further then, into the nature and properties of this luminous principle, and how we are related to, and affected by it.

183. **Exhilarating Agency of Light.**—Light is a stimulus to the nervous system, and through that, exerts an influence in awakening and

quickening the mind. The nerves of sense, the brain and intellect, have their periods of repose and action. The withdrawal of light from the theatre of effort is the most favorable condition, as well as the general signal, for rest; while its reappearance stirs us again to activity. There is something in darkness soothing, depressing, quieting; while light, on the contrary, excites and arouses. It is common to see this illustrated socially;—a company assembled in an apartment dimly lighted, will be dull, somnolent and stupid; but let the room be brightly illuminated, and the spirits rise, thought is enlivened, and conversation proceeds with increased animation. "Most delicate and mysterious is the relation which our bodies bear to the passing light! How our feelings, and even our appearance change with every change of the sky! When the sun shines, the blood flows freely, and the spirits are light and buoyant. When gloom overspreads the heavens, dulness and sober thoughts possess the mind. The energy is greater, the body is actually stronger, in the bright light of day, while the health is manifestly promoted, digestion hastened, and the color made to play on the cheek, when the rays of sunshine are allowed freely to sport around us."

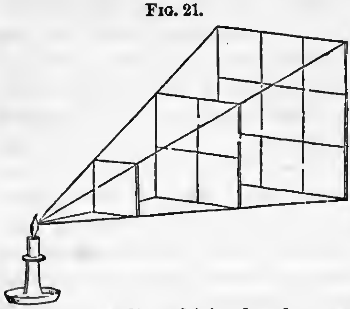
134. **Ancient Conceptions of Light.**—Light is that agent which reveals the external world to the sense of sight. The ancients believed it to be something born with us—an attribute or appendage of the eye. They thought that the rays of light were set into the organ of vision, and reached or extended away from it, so that we see in the same manner as a cat feels by the whiskers which grow upon its face,—by a kind of touching or feeling process.

135. **Newton's View of its Nature.**—Modern science regards light as an agent, or force, originating in luminous bodies, and flowing away from them constantly and with great rapidity, in all directions. But how? The human mind is never satisfied with the mere appearances of things. It demands a deeper insight into their nature,—an explanation of their causes. The first scientific attempt to explain the nature of light, and the cause of vision, likened the sense of sight to that of smell. We know that to excite the sensation of smell, material particles, emanating from the odorous body, pass through the air and are brought into contact with the olfactory nerve of the nose. It was supposed that light affects the eye as odors do the nose; that it consists of particles of amazing minuteness, which are shot from the luminous source, and entering the eye, strike directly upon the optic nerve, and thus awaken vision. This was the view of Newton, but it is now considered untenable and is generally rejected. It is at pres-

ent thought that light is *motion* rather than *matter*, and that the eye is influenced by a mode of action resembling that of the ear rather than that of the nose. We omit further reference to this question here, as the analogy will be more fully traced when we come to speak of colors (150).

136. **Light loses Intensity as it is Diffused.**—The rays of light proceeding from any source, a candle for example, spread out or *diverge*, as we notice nightly. As light thus diffuses from its source, the same quantity occupies more and more space, and it becomes rapidly weaker or less intense. This takes place at a regular rate. Its power *decreases* from each point of emission, in the same proportion that the space through which it is diffused increases, exactly as occurs in the case of radiant heat; and this is as the square of the distance. The light which at one foot from a candle occupies a given space, and has a given intensity, at two feet is diffused through four times the space, and has but one fourth the intensity; at three feet it spreads through nine times the space, and therefore has but one-ninth the intensity; following the law of radiant heat, as is shown in Fig. 21. If we are reading at a distance of three feet from a lamp, by removing the book one foot nearer to it, more than double the quantity of light will fall upon the page; and if we carry it a foot closer, we shall have *nine times* the amount of light to read by that we did at first. This effect, however, may be modified by the light reflected back from the walls, and which is always more, the whiter they are. Whitewashed walls and light-colored paper economize light, or give it greater effect than dark walls, which absorb or waste it.

Fig. 21.



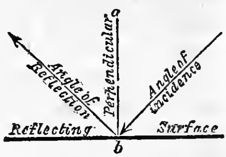
137. **How Bodies receive the Luminous Principle.**—When light falls upon various kinds of matter, they behave toward it very differently. Some throw it back (*reflection*); some let it pass through them (*transmission*); some swallow it up or extinguish it (*absorption*); and some, as it were, split it to pieces (*decomposition*). All bodies, according to their nature and properties, affect light in one or more of these modes, producing that infinite variety of appearances which the universe presents to the eye.

II. REFLECTION OF LIGHT.

138. Those bodies which will not allow the light to pass through them, are called *opaque*. When the rays of light strike an opaque body, a portion of them, according to the quality of the surface, is absorbed, and the remainder are thrown back into the medium through which they came. This recoil, or return of the rays, is called *reflection of light*.

139. **The Law of Reflected Light.**—When a ray of light strikes perpendicularly, or at right angles, upon a reflecting surface, it is thrown back in exactly the same path or line. If *a b*, Fig. 22, be a ray of light falling perpendicularly upon a reflecting surface, it will be thrown back in the same direction *b a*. But if the ray fall upon such a surface in a slanting or oblique manner, it glances off or is reflected, at exactly the same angle, as shown by the arrows. The angle of rebound is equal to the angle of striking; or, as it is commonly said,—THE ANGLE OF REFLECTION IS EQUAL TO THE ANGLE OF INCIDENCE, THE REFLECTED RAY IS ON THE OPPOSITE SIDE OF THE PERPENDICULAR, AND THE PERPENDICULAR, THE INCIDENT AND THE REFLECTED RAYS ARE ALL IN THE SAME PLANE. Place a looking-glass upon a table, in a dark room. Let a ray of light, entering through a hole in a window shutter, strike upon its reflecting surface, it will be thrown off at an equal angle, and both the incident and reflected rays will be made visible by the particles of dust floating in the room.

FIG. 22.



140. **How Reflected Light is scattered.**—Parallel rays falling upon a plane surface, are reflected parallel, as shown in Fig. 23; but separating rays falling upon such a surface are reflected divergently, or scattered. The beams of light from a candle Fig. 24 diverge before falling upon a mirror; and as each single ray makes the angle of incidence equal to that of reflection, it is clear that the rays must continue to diverge when they are reflected, as in the dotted lines in the figure. Thus when a burning candle is placed before a looking-glass, its diverging rays strike the mirror surface, and being reflected in divergent lines, are dispersed through the room.

FIG. 23.

141. **The Image in the Looking-glass.**—A highly polished metallic surface, called a *speculum*, is the most perfect reflector. Mirrors, or looking-glasses, consist of glass plates coated with metal. It is

not the glass, in looking-glasses, that reflects the light, but the metallic coating behind it. If we place any illuminated object before a plane mirror, rays of light pass from all points of its surface, and convey an image of it to the mirror. But the polished surface does not retain the image; it reflects or throws it back, so that the eye perceives it. The light which enters the eye comes from the real object, which *appears* behind the glass, because the angle or bend in the ray is not recognized. The light from an object may be reflected many times, and make a great number of short turns, but it will seem as if the rays came straight from the object, and it will always appear in the direction in which the last *reflection comes to the eye.* This will cause the image to appear as far behind the glass as the object is before it, as the accompanying diagram (Fig. 25) shows. A perfectly plane surface reflects objects in their natural sizes and proportions; but if the form of the reflecting surface be altered, made hollow (*concave*), or rounded (*convex*), they cause the image to appear larger or smaller than the objects; or the image is distorted in various ways, according to the figure of the surface. We see this constantly illustrated in the images of the face, formed by the bright metallic surfaces of domestic utensils.

FIG. 24.

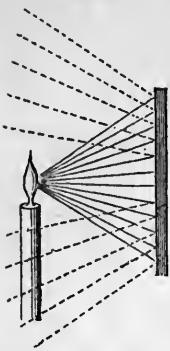
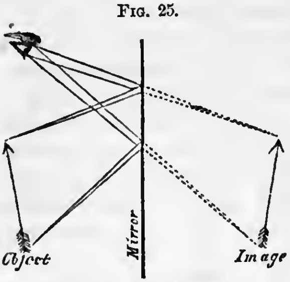


FIG. 25.



How the image appears behind the looking-glass.

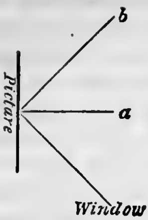
142. **A perfect Reflecting Surface would be Invisible.**—If the surface of an opaque body could be *perfectly* polished, it would *perfectly* reflect all objects placed before it, so that the images would appear as bright as the realities; but, in such a case, the reflecting surface would be *itself invisible*, and an observer looking at it could see nothing but reflected images. If a large looking-glass, with such a surface, were placed at the side of a room, it would look like an opening into another room precisely similar, and an observer would be prevented from attempting to walk through such an apparent opening, by meeting his image as he approached it. If the surfaces of all bodies had this property of reflecting light, they would be invisible, and nothing could be seen but the lights, or sources of illumi-

nation, and their multiplied images. Upon the earth's surface nothing would be visible but the reflected images of the sun and stars, and in a room, nothing except the spectres of the artificial lights, thrown back by one universal looking-glass. But perfect polish is impossible; there are no surfaces which in this manner reflect all the light.

143. **In what manner Light makes objects Visible.**—It is by *reflected* light that nearly every object is seen. No surfaces are perfectly flat; they may appear so, but, when closely examined, they are found to consist of an infinite number of minute planes, inclined to each other at all possible angles, and therefore, receiving and reflecting the light in all possible directions. If a ray is let into a dark room, and falls upon a bright metallic surface, a brilliant spot of light will be seen from certain points, but the reflecting surface will be almost invisible in other directions, and the room will remain dark. If, now, a sheet of white paper be substituted for the mirror, it can be seen in all directions, and will slightly illuminate the apartment. The surface of the paper scatters the light every way, producing an *irregular* reflection. It is this scattered and diffused light which makes the surfaces of objects visible. Thus light irregularly reflected exhibits to us *real objects*, while light regularly reflected discloses only *semblances* and *images*. We see the image in a looking-glass, by light regularly reflected; we see the surface of the glass itself, by the light scattered by the minute inequalities of its surface. This irregularly reflected light diverges from each point of every visible surface *in all directions*, so that the object may be seen from whatever point of view we look at it, provided other light does not interfere (144). It follows the law of radiation, that is, it flows from each point as a focus, but it does not conform to the principle of regular reflection, which has just been noticed. *The direction of the reflected rays is independent of each of the incident rays.* In this manner light is radiated from surface to surface, so that in the immediate absence of any original luminous fountain, there is a reverberation of light from object to object, through an endless series of reflections, so that we have general and equal illumination.

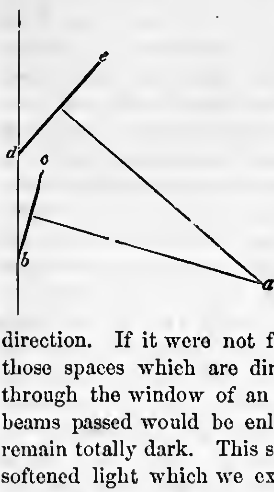
144. **Management of Light in hanging Pictures.**—The foregoing principles are variously applicable; hanging pictures upon the walls of rooms may be taken as an illustration. As it is irregularly reflected light that reveals to us the picture, it should be so placed that from the most natural point of observation *that* light reaches the eye, and not *regularly* reflected light. If the light fall upon a picture from a window on one side of it, and we stand upon the other side, as at *b* (Fig.

FIG. 26.



26), the eye is filled with the glare of the regularly reflected light, while the picture itself can hardly be seen. In such a case, the true position of the observer is perpendicular to the plane of the picture, as at *a* in the figure. As pictures are often suspended higher than the eye, they require to be inclined forward, and the *degree* of their inclination should depend upon their height and the distance of the point at which they may be best observed. They should be inclined until the line of vision is perpendicular to the vertical plane of the picture. With the eye at *a* and the picture at *b* (Fig. 27), its proper inclination would be to *c*; but if it were elevated to *d*, it should fall forward to *e*. We will further remark that pictures should be placed as nearly as possible in the same relation to light as when they were painted; that is, if the shadows fall to the right, the illumination should come from the left to produce harmonious effects.

FIG. 27.



145. **Light scattered by the Atmosphere.**—By this kind of irregular reflection, the atmosphere diffuses and disperses the light,—each particle of air acting as a luminous centre, radiates light in every direction. If it were not for this, the sun's light would only enter those spaces which are directly open to his rays, so that, shining through the window of an apartment, that portion only where the beams passed would be enlightened, and the rest of the room would remain totally dark. This secondary radiation occasions the mild and softened light which we experience when the heavens are screened with clouds, instead of the intense and often painful glare of a cloudless summer day. In the same manner the atmospheric particles scatter the rays and diffuse a subdued illumination at morning and evening twilight, while the sun is below the horizon.

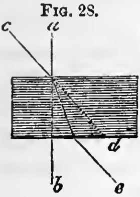
III.—TRANSMISSION AND REFRACTION OF LIGHT.

146. When light falls upon transparent objects, as air, water, glass, it passes through or is said to be *transmitted.* Bodies vary greatly in this power of passing the light, or *transparency.* The metals are least transparent, or most opaque, yet they are not entirely so; thin

gold leaf, for example, transmits a greenish light. Nor are there any bodies which transmit *all* the light; the most transparent detain or absorb a part of it. A considerable portion of the sun's light is absorbed in the atmosphere; it does not reach the earth; and it has been calculated that if the atmospheric ocean were 700 miles deep, the solar light would not pass through it, and the earth would be in darkness. The purest water of a depth of seven feet, absorbs one half the light which falls upon it, and of 700 feet depth, extinguishes it.

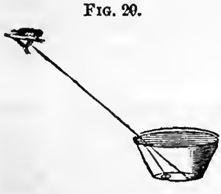
147. **Fracture or Refraction of the Rays.**—When light passes from one substance to another of a different density, as from air to water, it is liable to be turned out of its straight course. If it pass from one medium to another in a line perpendicular to its surface, as *a b* (Fig. 28), it will not be diverted; but if it fall at an angle, as at *c d*, it will not continue straight to *d*, but will be as it were broken or *refracted* and proceed to *e*. If the refracting medium have parallel surfaces, the ray on leaving it is again bent back to its original course, as is shown in the figure. For this reason common window panes, which consist of plates of glass with parallel surfaces, unless they contain flaws, produce no distortion in the appearance of the objects seen through them. When light passes obliquely from a rarer to a denser medium, as from air to water, it is turned *toward* a perpendicular; when from a denser to a rarer medium, as from water or glass to air, it is turned *from* a perpendicular, as shown in Fig. 28.

FIG. 28.



148. **How Refraction may be shown.**—A stick, with half its length placed obliquely in water, appears bent at the surface; this is because the *rays* are bent, so that those which come from that portion of the stick which is in the water, show it in a false place. Put a coin in any opaque dish upon a table, and step back, until the edge of the vessel just hides it from view. Now, if water be carefully poured in, without disturbing its position, the coin will become visible (Fig. 29), the rays of light coming from it, which before passed above the eyes of the observer, are now, as they come into the air, bent downward *from the perpendicular*. Bodies possess different degrees of refractive power. When we look through a mass of water, as in a pond or stream, the rays are so altered that it appears only three-quarters as deep as it really is. Cases of drowning have happened through ignorance of this

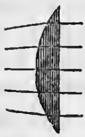
FIG. 29.



illusion. The degree to which any substance bends the light from its straight course is called its *index of refraction*. Each transparent body has its *refracting index*, which is one of the properties by which it may be known.

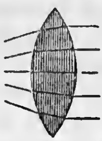
149. **Effect of Lenses upon Light.**—This power which bodies have, of bending light from its straight course, is employed when we desire to gather it to a point or focus, or to concentrate it; or when it is wished to disperse and diffuse it. Pieces of glass, cut or ground into various shapes, are commonly used for this purpose, and are called lenses. A plane convex lens (Fig. 30), or a double convex lens (Fig. 31), collect the rays of light; while a plane-concave lens (Fig. 32), or a double-concave lens (Fig. 33), separate them, or spread them out into a greater space. Common spectacle glasses are examples of these forms of lenses (248).

FIG. 30.



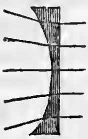
Plane-convex Lens.

FIG. 31.



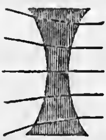
Double-convex Lens.

FIG. 32.



Plane-concave Lens.

FIG. 33.



Double-concave Lens.

IV. THEORY OF LIGHT—WAVE MOVEMENTS IN NATURE.

150. **Light not Matter but Motion.**—Thus far we have considered light as if it were simple, without inquiring if it be really so, or compounded of different elements. There is another way in which the objects of nature receive and dispose of it, which brings us to the question of *composition*, and the subject of color. But what is color? and what is light, in nature and essence? Or what opinion has been formed of it, by those who have thought upon the subject most deeply? In its cause and mode of movement, light is believed to resemble sound; it is propagated, not by moving particles of matter, but by impulses of motion, which progress unaccompanied by any material substances. Let us note how wave-motions take place, and the known extent of their occurrence in nature.

151. **Visible Wave Motions in Nature.**—If we fasten one end of a cord, and holding the other strained tight, move the hand sharply up and down, or from side to side, *waves* will be formed, which proceed along the string. The *real* motion, in this case, is at right angles to the direction of the string, the *apparent* motion is forward. The particles

composing the cord make excursions right and left, or up and down, which gives rise to forward wave-impulses. All have noticed what takes place in a field of grain when the wind blows. A succession of waves appear to pass over the field; but it is not the grain that moves along over the ground; every stalk keeps its place, and only bows its head. Yet wave-motions are seen to flow successively forward. If we toss a stone into perfectly still water, the surface will be thrown into agitation, and waves will pass rapidly from the point where it struck, outward, in all directions. The water in this case does not move forward any more than the grain did. This is proved by the circumstance that any objects which may be seen floating upon the water are not carried along by the advancing waves, but only move up and down in their places. Thus, particles of water, moving *vertically*, cause wave-motions to travel *horizontally*.

152. **Sound the result of Waves in the Air.**—Air is the medium which conveys sound to the ear. If a bell be rung in a vacuum, we cannot hear it. The air in some way transmits or conveys the sound from point to point. How is it done? There is no passage of air-particles, no current or breeze moving from the sounding body to the ear; the atmospheric medium is thrown into vibratory motion, and it is air-waves only which move forward. We all know that sonorous bodies vibrate when struck, and that sound results. A harp-string, when struck by the fingers, swings rapidly backward and forward for a certain time, producing a sound as long as the vibration lasts. A piece of steel wire, or a pin held between the teeth, utters a sound as often as the free end is inflected. By touching the teeth with the prongs of an excited tuning-fork, we can *feel* the vibrations. Sound is thus not only motion, but it is *vibratory* motion, and its transmission to the ear is due to the flight of air-waves, which, striking against the auditory drum, communicate sensations of sound to the brain through the auditory nerve.

153. **Upon what the differences of Sound depend.**—If sounds are thus caused by vibrations, it would seem that the *quality* of sound should depend upon the quality of the vibrations; which is the fact. The first distinction among sounds is into high and low, or acute and grave; it is a difference of *pitch*. Slow vibrations produce grave sounds of a low pitch. In the case of strings, for example, the larger they are the heavier they are, and the looser they are the slower are their vibrations, and the deeper are their sounds; while, on the other hand, the shorter, lighter, and tighter they are the quicker are their vibrations, and the higher and sharper the sounds they give. Each

sound, therefore, that can be made, is the result of a certain *number* of air vibrations, and to that pitch of sound always belongs that number. SAVART contrived a machine by which the number of pulsations which belong to each tone has been determined by actual experiment. A thin plate of metal was struck by each tooth of a revolving cogged wheel, the motion of which was easily measured. In this way he determined the exact number of vibrations in the tones forming the usual musical scale.

154. **Harmonic Ratios of the Musical Scale.**—It was found, experimentally, that the orchestra pitch note A, of the treble cleff, is produced by 853 vibrations per second. The number of pulsations in each note of the octave is as follows:

RATIO OF HARMONIC SOUNDS.

No. of Vibrations——512, 576, 640, 682, 768, 853, 960 1024,
Intervals —— 64, 64, 42, 86, 85, 107, 64.

It will be seen that in the highest note of this scale there are just twice as many vibrations as in the lowest; the interval which they comprise is called an *octave.* The difference between the number of pulsations in any note, and the same note in the octave above, is as 1 to 2. Hence, by halving the numbers of any scale we obtain the numerical value of the octave below; while by doubling them we have the number of vibrations made by the notes in the scale above. The lowest note of a seven octave piano is made by 32 vibrations in a second, and the highest by 7,680. Two tones having exactly the same number of vibrations are said to be in *unison.* When their numbers are not the same, but are in some simple relation, a *concord* is produced. If one has twice as many as the other an *octave* results, which is the most pleasing of all concords. The simpler the numerical ratio between the vibrations which generate a sound, or the air-waves which reach the ear, the more perfect and sweet the concord. When the difference is such that the *proportion* cannot readily be recognized by the ear, *discord* is the result. The whole phenomena of music thus resolve themselves into certain harmonious numerical ratios among air-waves, by which impressions are produced in a certain exact order, upon a mathematically constituted organ—the brain.

155. **Light and Colors result from Wave Motion.**—As all sound and music are thus due to measured wave movements in the air, it is thought also that *light* has a similar origin. This view assumes, that throughout the universe there exists a subtle, all-pervading and infinitely elastic *ether*, and that vision is the result of vibrations or wave movements sent through this ether, from the source of light to the nerve of the eye; and as different musical sounds are produced by varying rates of vibration in the air, so it is suspected that different colors are due to the different rates of vibration in the luminous ether, and philosophers have gone so far as even to measure the wave-lengths of the different elements of light. By wave-length is meant the distance from the top or crest of one wave to that of the next; and it is inferred from certain interesting experiments made by NEWTON, that the length of waves, although exceedingly small, differs in the different colors, red being largest and violet smallest. In an inch length of a ray of red light there are 37,640 vibrations; in an inch of yellow light, 44,000; and in an inch of the violet ray, 59,756. If the minuteness of the wave excite surprise, it may be replied that this is by no means the strongest illustration of the smallness of the scale upon which nature's works are often constructed. Indeed, in this case it has been even outstripped by art. M. NOBERT, of France, has ruled lines upon glass, for microscopical test-purposes, but the $\frac{1}{75000}$ of an inch apart.*

156. **Vibrations per second of the luminous Ether.**—But the demonstrations of science carry us into far profounder regions of wonder. The speed of light has been measured; the velocity with which it moves is in round numbers 200,000 miles per second. That is, when we look at any thing, an agent or force sent from the illuminated body streams into the eye at the rate of 200,000 miles in a second. Knowing the rate at which light moves, and the number of waves in an inch for any particular color, it is easy to ascertain the number of vibrations made by each in a second. In two hundred thousand miles there are a thousand millions of feet, and, therefore, twelve thousand millions of inches. In each of these inches there are forty thousand waves of red light. In the whole length of the red ray, therefore, there are four hundred and eighty millions of millions of waves. Now as this ray enters the eye in one second, and the retina pulsates once for each of these waves, we arrive at the astonishing conclusion, that where we behold a red object the membrane of the eye trembles at the rate of *four hundred and eighty millions of millions of times* between every two ticks of a common clock. Of yellow

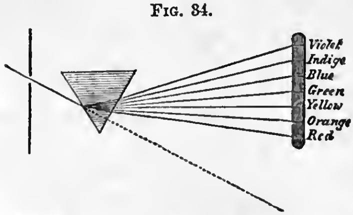
* See Appendix B.

light five hundred and thirty-five millions of millions of waves enter the eye, and beat against the nerve of vision in the sixtieth part of a minute; "if a single second of time be divided into a million of equal parts, a wave of violet light trembles or pulsates in that inconceivably short interval seven hundred and twenty-seven millions of times." Vision is undoubtedly the result of something *done* within the eye, the effect of an active external agent, and the reaction of the mechanism; the chemical constituents of nervous matter,—perhaps the atoms of carbon or phosphorus are in some way changed or influenced by nerve impulses in infinitely rapid succession, the sensations of vision and color being the consequence. If it be objected that the foregoing statements are incredible, we reply that they are generally accepted by the most sober and cautious scientific thinkers. But they are really no more strange or impossible than many other of the miracles of being which science is constantly unfolding around us. We should observe a due modesty in criticising and assigning limits to the wonders and perfections of God's works. Dismissing the more purely theoretic or explanatory aspect of the subject, we now proceed to notice those properties and relations of colors which are the result of actual examination.

V.—COMPOSITION AND MUTUAL INFLUENCE OF COLORS.

157. **White Light taken to pieces.**—If a ray of common white light be admitted, through a small aperture, into a dark room, and be made to strike upon a triangular piece of glass (*prism*), the white ray disappears; it is turned from its course, and there falls upon the opposite wall an oblong colored image called the *solar spectrum*. It consists of seven bright colors, always found in a certain order, as shown in Fig. 34; but they pass into each other gradually, so that it is difficult to tell where one ceases and another begins. NEWTON assumed, as the result of this experiment, that white light is a compound principle, consisting of these seven colors, which he called *primary*, and taught that all other colors whatever are the result of various commixtures of these. For convenience of representing the relations of colors, we may represent white light by a circle, and the

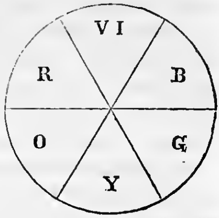
FIG. 34.



Separation of white light into Newton's seven prismatic colors.

colors which compose it by divisions of the enclosed space. In that case the seven primaries of NEWTON will be shown as in Fig. 35.

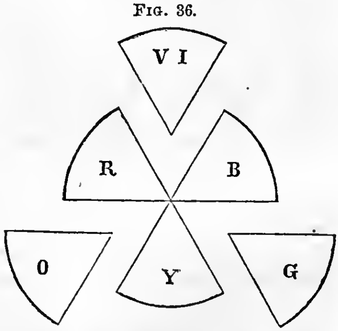
FIG. 35.



158. **Newton's explanation of Colored Surfaces.** —White light falls upon objects, and they appear colored: how is this? NEWTON replied: bodies have not only the power of reflecting and transmitting light, but they can also decompose and absorb it. A body appears white because it reflects back to the eye the white light that falls upon it, unaltered. When white light falls upon a surface and it appears *black*, it is *absorbed* and lost in the substance, and therefore does not return to make an impression upon the eye. But the blackest surfaces do not really absorb *all* the light, for then they would be invisible, and appear like dark cavities, presenting no surface. If the surface appears colored, it is because the white light is split up, or decomposed, one part being absorbed and lost, while the other is reflected to the eye, so that the object appears of the reflected color. For example, grass absorbs all colors but green, which it reflects to the eye; and in the same way the sky absorbs all but blue, and reflects *that* to the eye. Different surfaces reflect the primary colors mixed in all manner of ways, and hence the endless modifications of color that meet the eye.

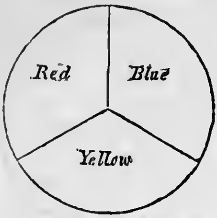
159. **But three Primary Colors.**—A more simplified view of the composition of colors has been propounded by Sir D. BREWSTER, and generally received. He considers that instead of seven, there are but three elementary colors, red, yellow, and blue, and that the others are compounds of these. We cannot produce red, yellow, or blue, by the mixture of any other colors; but we *can* produce all others by the various combinations of these three. BREWSTER maintains, that even the colors of the spectrum are not absolutely pure, but that each of the three exists throughout its whole extent, although greatly in excess at the different points where they are visible. Blue, yellow and red being primaries, violet, indigo, green and orange are secondaries derived

FIG. 36.



from them. The separation of the impure or compound colors from the spectrum, leaving the three from which they are derived, is illustrated in Fig. 36. Orange is derived from the mixture of red and yellow; green from yellow and blue; and indigo and violet from blue and red. So that we have white light at last composed only of the three colors, as represented in Fig. 37.

Fig. 37.



160. **What are Complementary Colors.**—The effect of a colored surface is to decompose the white light which falls upon it, reflecting one portion, and absorbing or extinguishing the rest. We do not see any colored surface, except by the seperation of the light which falls upon it into two colored parts, the one visible, the other absorbed. Now it is evident that the rays absorbed, added to those which are reflected, make up the ordinary light. Hence, whatever be the color reflected, that which is not reflected, and which is, therefore, wanting to *complete* the full set of colors which form white, and make out the full *complement*, is called the *complementary* color. The part absorbed, or which does not appear, is the complementary of the color seen. This may be made perfectly clear by the circular diagram. If we look, for example, upon a red surface supposed to be presented in Fig. 38, yellow and blue are seen to be the colors necessary to complete it to white; they are therefore the *complement* of red; but yellow and blue form *green*, as shown in Fig. 39, which is therefore the true complement of red, that which it lacks to make white. If we look upon a yellow surface (Fig. 40), blue and red are deficient; blue

Fig. 38.

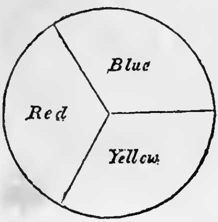


Fig. 39.

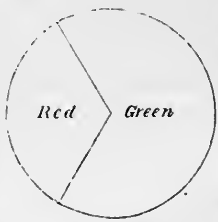


Fig. 40.

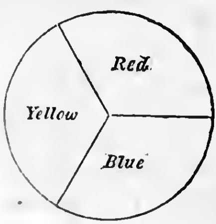
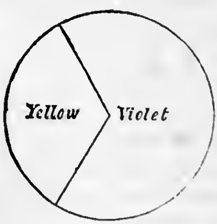


Fig. 41.



and red produce violet, therefore violet is the complementary of yellow, as seen in Fig. 41. Again, we look upon blue (Fig. 42); red and yellow are required to complete the circle into whiteness; but red and yellow make orange, therefore orange is the complement of blue, as is shown in Fig. 43.

FIG. 42.

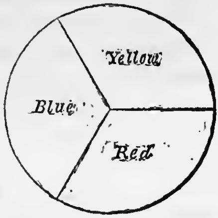
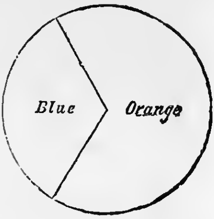


FIG. 43.



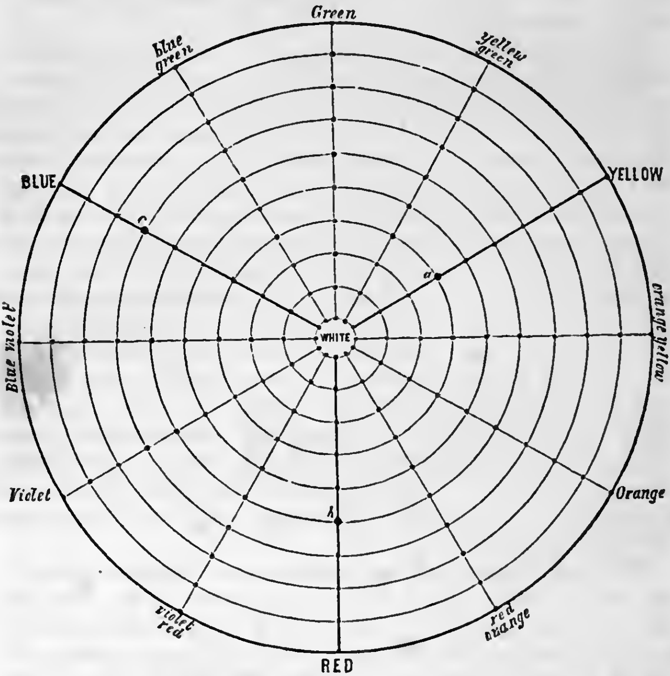
161. **Tints and Shades, Tones and Scales.**—These terms have formerly been employed in the most loose and indefinite way; they have, however, now acquired a kind of scientific precision. The tones of a color are those aspects which it presents when altered from its maximum of brightness or highest intensity, by mixing with it either white or black: if we take the purest and brightest red as a standard, say carmine, and mingle various proportions of black with it, we of course darken it and get deeper tones of red. If we mingle white with it, we lighten it and get lighter tones of red. By the addition of black the red is said to be *shaded*, by the addition of white it is *tinted*. Each color, in this case, is a tone of red, and the whole series of tones constitute a *scale*—the *red scale*. It may consist of ten, twenty, or fifty tones, according to the quantities of black and white successively added. In the same manner we make tones of orange and get an orange scale, tones of blue and get a blue scale, and so *each color has its scale*, in which it moves in two directions, from its normal or standard point, towards black and towards white.

162. **What are Hues?**—A hue is the result of the movement of a color, not in the direction of black or white, but of some other color *out of its scale*. If a little blue be mingled with red so as to change it slightly, the red still predominating, a *hue of red* is produced. So if blue be tinged in a similar manner by any color, hues of blue result. In the same way are produced hues of orange, yellow, violet, green, &c.

163. **Chevreul's scheme for showing the relation of Colors.**—A plan has been suggested by M. CHEVREUL, of France, for representiug the composition and relations of colors, in an extremely simple and effective way. It clears the mist from the subject, and not only discloses it in a beautiful order, but is very valuable for practical purposes. It is represented by the diagram (Fig. 44). The outer circle represents

black, the centre white. The radial lines passing from the centre to the circumference represent scales of color, each dot indicating a tone. Each scale comprises ten tones. Take the red scale for example. The larger dot at *h* represents the place of its normal, or type of the purest red; from that point toward the circumference it is shaded down to black, and in the other direction it is tinted up to white. The same

FIG. 44.



Plan of CHEVREUL'S CHROMATIC CIRCLES, illustrating the principle of complementary colors, tints, shades, tones, hues, and scales.

with yellow; its normal is at *a*, and that of blue at *c*. From these three primaries all the rest are derived. Midway between yellow and blue is the scale of green, which results from their combination in equal proportions, half blue and half yellow. Midway between green and blue is a scale that we might call a greenish blue. It is only one-quarter of the distance from blue to yellow, and therefore is three-quarters

blue, and one-quarter yellow,—a hue of blue. Space or distance represents proportions of color. It will be seen that colors may be altered in two ways, that is, may move in two directions—*along* their scales, by admixture with white or black, producing *tones*, and *out* of their scales, in the direction of the circles, producing *hues*. The diagram represents twelve scales, with ten tones on each scale, giving an arrangement of 120 colors, each having a definite, known composition. With 24 scales, and 24 tones on each scale, we should have a scheme of 576 colors.

164. **Making a Chart with the real Colors.**—An instructive exercise is to produce such a chromatic chart with the actual colors. Make a circle upon paper a foot in diameter, designed for twelve scales of ten or twelve tones. From a box of paints select carmine for the normal red, gamboge for the normal yellow, and Prussian blue for the normal blue. By mixing the blue and red with a pencil brush in equal proportions, the violet is produced, and by varying the proportions all the hues between blue and red are obtained. By mixing blue and yellow, green, greenish-yellow and yellowish-green are made; and by mingling red and yellow, orange, orange-yellow and yellow-orange are made. Thus all the hues are obtained. By mixing each with black and white, increasing the proportion of black regularly as you proceed outwards, and white as you go inwards, the scales will be formed. Familiar colors would at once locate themselves upon such a chart, so that we should understand their exact composition. For example, the crimson will be found near the red, but in the direction of blue, that is, it is red slightly blued, while scarlet is red, moved slightly in the opposite direction, toward yellow. So indigo is blue just started toward red.

165.—**How the Diagram shows Complementary Colors.**—We determine the complementary of any color in a moment, by a glance at the system of circles. For example, we want the complementary color of red; this is formed by the union of blue and yellow, producing green. Green, therefore, which is the complement of red, is placed exactly opposite to it on the diagram. So, opposite blue we see its complement orange, and opposite yellow, violet, which is *its* complement, and also the contrary; the complement of green is red; of orange, blue; of violet, yellow. So of all the scales, no matter how many are formed, their complements are seen on exactly opposite lines of the circle. The complement of red-orange is observed to be blue-green; of a reddish-violet, it is greenish-yellow, and so on round the whole circle. We may even say that the complement of black is

white, and of white, black,—of a deep tone on one side, it will be a light tone on the other. Thus the complementary color of a deep tone of green will be a correspondingly light tone of red; of a light tone of violet, it will be a deep tone of yellow. By means of the diagram, therefore, the complementary of any of the one hundred and twenty colors can be found by any one in an instant; a fact of much practical importance, as we shall soon have occasion to see.

166.—**What is meant by Complementary Contrast.**—By a glance at the diagram it will be seen that the complementary of any color is its exact opposite. It is the color which differs from it the most possible; therefore it is in strongest *contrast* to it. Complementary colors are, hence, contrasted colors, and their relation is commonly indicated by the term *complementary contrast.*

167. **Luminous and sombre Colors.**—It will be noticed that the three normals (Fig. 44) of red, yellow, and blue (represented by the larger dots), are not all located at equal distances from the circumference or centre. The reason of this is obvious. Yellow is a light, and blue a dark color. The natural position of yellow, therefore, at its height of intensity, is nearer to the white than to the black, and the natural position of bright blue is much nearer to the black than to the white, while red is intermediate. For this reason it requires more tones to shade yellow down to black than it does blue, and more also to tint blue up to white than it does yellow. Colors are thus divisible into *luminous* and *sombre.* Those into which yellow enters most largely, belong to the first class, and those consisting mainly of blue, to the second, red forming a *medium* color.

168. **Grays and Browns; Pure and Broken Colors.**—Grays result from the simple mixture of black and white. Browns are the result of mixing black with the various colors. The deeper tones of all the scales upon the diagram are browns. A color which has no black in it is said to be *pure*, while the addition of black produces a *broken* color. The browns are therefore all broken colors. A color may be broken, however, without directly adding black; the three primaries mixed in certain proportions produce this effect. If a little blue, for example, be added to orange, it neutralizes a portion of the yellow and red, breaking the color and starting it towards black.

169. **No Colors perfectly pure.**—We must guard against the error of supposing that in practice we meet with any such thing as a pure or perfect color. Even those of the spectrum or rainbow are not perfect; BREWSTER has shown that the very brightest is contaminated by others. But when we leave the spectrum, and begin to deal with the

commoner aspects of colors, paints, dyes, &c., their imperfections become much more obvious. We are to regard a red surface as reflecting to the eye, not a simple and perfect red, but along with the red a certain portion of the other colors of the spectrum, which have the effect of weakening and lowering the red. The true statement is, that the sensation of red is the result only of the *predominance* of that color. It is the same with all the colors we see; others are more or less mixed with them, which impair their brightness.

170. **How Colors mutually improve each other.**—The action of colors upon each other is not a matter of hap-hazard, and although it was long inexplicable, and half suspected to be a field where nature capriciously refused to be curbed by rules, yet science has at length discovered the reign of law in the domain of colors. Some combinations of colors are pleasing to the eye, and others disagreeable; some are harmonious, and others discordant. The harmonies of color are of several kinds, but the fundamental and most important one is the *harmony of complementary contrast.* If a purchaser be shown successively a dozen pieces of bright-red cloth by a shopkeeper, those last seen will be declared much inferior in intensity of color to the first, such being the actual appearance which they present to the purchaser's eye. If now the buyer's attention be directed by the merchant to green stuffs, they will appear extremely bright, unnaturally so; and if the eye recur again to the reds, they will look much finer than before. Red and green viewed in this way have the mutual effect of improving each other. It is the same if the two colors be placed side by side and observed together; they will so heighten each other's intensity as to appear much brighter and purer than when they are viewed separately, that is, when the eye cannot be directed from one to the other. If now we take yellow and violet, or blue and orange, or violet-red and yellow-green, and observe them in the same manner, we shall get the same result; their brilliancy and clearness will be mutually heightened. But these colors are complementaries of each other; complementaries then, when viewed together, improve each other. They are the most opposite or contrasted, and therefore the pleasing effect they produce upon the eye is denominated *Harmony of Complementary Contrast.* These effects are experimental facts which may be verified by any one. Take six circular pieces of paper, say an inch and a half in diameter, and color them respectively red, orange, yellow, blue, green, and violet. Place each one separately on a sheet of white paper, and then, with a thin wash of color, tint the white paper around each circle with its complementary color, gradually

weaker and weaker as the tint recedes from the colored circle. If now the red circle be placed upon the sheet that is colored green, it will be made to appear greener; so if the green circle be placed upon the reddened sheet, the latter color will be at once brightened. It will be found upon trial, that each color when viewed with its complementary, increases its intensity or improves it. We get by such experiments two kinds of result; first, a *successive* change where one color is viewed after another; and, second, a *simultaneous* change when both colors are seen at once and together. Both these effects require to be explained, and first of *successive contrast.*

171. **Colors exert an influence upon the Eye.**—Colors *appear* to exist upon the surfaces of external objects, but we must not forget that their real seat is in the eye itself; that is, external bodies so modify the light, that it produces within the eye different effects, which we name colors. Colors are sensations, or nerve-impressions, the result of something accomplished within the optic organism. Thus we say snow is white, and blood is red; meaning thereby that snow so influences the light, that it originates within the organ of vision a sensational effect which we style *white;* while blood so modifies the light falling upon the nerve of the eye as to cause the perception of *red.* As color thus finally resolves itself into *different modes of affecting the eye*, we might naturally expect that both the agent and its organ would react upon each other,—colors producing changes in the eye, and the eye producing changes in colors, more or less considerable, according to circumstances. The eye being a part of the bodily system, and governed by general physiological laws, is subject to the same vicissitudes of varying activity, acute and blunted susceptibility, as other parts. We shall now notice the change that takes place, only so far as colors are themselves affected; deferring to another place an examination of the influence of colored light upon the eye in reference to its health (253).

172. **Duration of Impressions upon the Retina.**—Impressions continue upon the nerve of the eye about one-sixth of a second after the object is removed. For this reason, a torch whirled swiftly round appears as a continuous streak or ribbon of fire. But the eye continues to be affected for a much longer time; although it is not, as we might at first suppose, by a feeble, lingering impression left upon it, which gradually fades out after the object is withdrawn from sight. If there were a continuance of the perception of an object after its removal, the effect of viewing another object would be the mixture of two colors. For example, if a bright blue object were seen, and then the

eye suddenly directed to a red, the effect would be a perception of a mixture of the two, or violet, and this would remain until the first impression, or blue, faded away from the retina, after which the red object alone would be perceived. But such is not the case.

173. **The Eye loses its sensibility to Colors, and demands their Complementaries.**—The influence of any color upon the eye is to diminish or deaden its sensibility to that color; it gets fatigued in looking at one color for some time, so that it appears less bright. If, for example, the gaze be directed for a time upon a bright red object, that part of the retina upon which the image is impressed, becomes exhausted by the action of the red color, and partially blinded to its brightness; just as the ear may be *deafened* for a moment by an overpowering sound. But the effect does not stop here. If the eye be averted from the red and directed to white, the red contained in the white will not produce its natural effect, while the balance of the colors in white, blue, and yellow, make their proper impression upon the eye, producing green. Thus the eye, dulled to one color, has a tendency to see its complementary. If we place a red wafer upon a sheet of white paper, and fix the gaze upon it steadfastly for some time, and then toss it off, we shall see a spectral image of the wafer upon the paper, *but it will be green.* The wafer so extinguished the sensibility to red upon a certain portion of the retina, that when it was removed, the eye saw the white, *minus the red*, that is, green. In like manner, if the eye be impressed with green, it loses its sensibility for it, so as again to decompose white and see red. If blue is observed, the impressibility of the nerve of sight is lowered for *that* color, so that white light is seen without its blue, and *orange* appears, which is the complementary of blue. In like manner the observance of *yellow* creates a tendency to see *violet*, and in the same way the effect of any color whatever, is to dispose the eye to see its complement. If we gaze at the sun at sunrise, when of a ruddy appearance in consequence of his rays being strained of their blue and yellow as they pass through the damp atmosphere near the ground, an image will be generated by the eye *formed of these missing rays*, and, therefore, green. When he has ascended higher and become of an orange yellow color, the image will be dark violet. It is well known that in looking at the sun through colored glasses at the time of an eclipse, spectres of the solar disk are sometimes produced which continue for a time before the eye. The color of these is always complementary to the color of the glass through which the sun was viewed.

174. **Simultaneous contrast of Colors.**—But colors placed side by side,

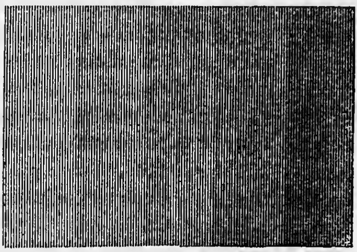
exert upon each other, *simultaneously*, an influence that can hardly be accounted for by the theory which explains *successive* contrast. The effect is of the same kind,—contrasted colors are augmented in brightness, but it results from the equal action of both colors upon the eye at *the same time.* It has been stated that surfaces reflect to the eye rays of other colors beside those which appear. No surface can so perfectly analyze the white light which falls upon it, as to absorb *all* of one color, and reflect *all* of another. It appears of the color of the predominating ray, though more or less of the remaining colors of white light are reflected also, and diminish its purity. We look upon a red; it is not perfect, because other colors *not red*, but the opposite of red, are mingled with it and reduce its effect. We gaze separately upon green; it is vitiated by rays coming from it that are not green, but its opposite. Now if we could clear away or destroy these vitiating rays, we should improve both colors, and this is actually done by placing them side by side. The reducing colors, which are active when the surfaces are viewed *separately*, seem to be, in some way, neutralized when they are brought together, and the complementary of each is thrown upon the other.

175. **How associated Colors injure each other.**—If certain combinations of color alter each other for the better, it is easy to see how other combinations must act in other ways for the worse. If the mutual effect of colors most contrasted be to intensify and exalt each other, it follows that if those most nearly alike are associated together, they will vitiate and injure each other. What the exact effect will be, may be seen at once by inspecting the chromatic diagram. The complement of violet is yellow. If violet be associated with yellow, therefore, the only effect it can produce is to make it yellower; but suppose it be placed beside other colors, the result must be a tendency to yellow them all. Violet placed beside green drives it out of its scale (see diagram) toward yellow. It was half yellow before, but the effect of violet is to increase the proportion of this element, and thus produce a new hue of yellowish-green. If violet be placed beside orange, which is also half yellow, it is moved out of its scale in the same direction as before toward yellow, a hue of yellowish orange being produced. As orange and green are already half yellow, it is obvious that the effect of adding to them a little more yellow will not be so marked as when this color is cast upon those which do not contain it. Violet, beside blue, stains it of a greenish hue; while beside red it changes it to scarlet. By tracing these effects out upon the diagram we at once get at the general law of the mutual influence

of colors. A color placed beside another *tends to make that color as different as possible from itself.* In the case of violet just alluded to, by reference to the diagram it will be seen that the color naturally farthest from it, by its very constitution indeed exactly opposite to it, is yellow. Now if bright violet be placed beside the yellow scale, it will drive every tone of that scale one or two steps back, away from itself, by making them all still yellower, and you will notice that the effect of violet upon the other colors, by throwing yellow upon them, is to start every one of them away from itself in the direction of its antagonist, which is the yellow. If traced out it will be seen that the effect of any other color is precisely the same. The complementary of any color thrown upon another renders it more unlike, or increases the difference between them.

176. **Contrast of Tone.**—The effect of viewing white and black together is to heighten the contrast between them, and so with the intermediate tones of a scale of white and black. The accompanying wood-cut (Fig. 45) affords an imperfect illustration of this effect. It consists of five bands, shaded successively deeper and deeper from left to right. As the eye glances at the scale, the bands appear darker at their left borders and lighter at their right. But this appearance is an effect of contrast; for if we take two slips of paper with straight edges, and cover all the diagram but any single band, its surface will be seen to be perfectly uniform. When viewed together, however, there is a heightening of the real differences, the light tones seem lighter and the dark tones darker, almost as if the intention was to represent fluting. It is so with the different tones of *any* color which has been shaded with black or tinted with white. If we place two different tones of the same color together, they always alter each other's intensity; dark tones making adjacent light ones appear still lighter, and light ones making dark tones seem still darker. This is, perhaps, because the absence of light in the dark color renders the eye more sensitive to the white light of the lighter color, and on the contrary the dark color appears darker, because the white light of the lighter color destroys the effect of the small amount of white light reflected by the other. Thus if we place

Fig. 45.



Illustrating the effect of contrast of tone.

L. &C.

a dark red beside a light rose-color, or a deep yellow in contact with a straw-color, they will, as it were, push each other further apart, the light tones in both cases appearing lighter, and the deep ones deeper, so as to deceive the eye in regard to the real depths of their colors. Thus for tones as well as hues the law of CHEVREUL holds good. "*In the case where the eye sees at the same time two contiguous colors, they will appear as dissimilar as possible, both in their optical composition and the height of their tone.*"

177. **Harmonies of Analogy.**—The employment of glaring or intense colors in many cases, as often in dress, is not admissible by the rules of cultivated taste. It is chiefly among the rude and uncultured that we remark a passion for gaudy and flaunting colors. With the progress of a refined civilization there is a tendency to the employment of more subdued colors in personal and household decoration. Not by any means that good taste requires the total rejection of bright colors, but only that they be used with skill and discretion—be ameliorated by combination, so as not to produce staring and stunning effects, or strong and deep contrasts which often offend the eye. Harmonies of complementary contrast are to be first and chiefly sought in chromatic arrangements; but these are comparatively limited, and in the demand for variety, other concords are found, which, although less striking, often give beautiful results. In studying the best arrangement of colors to produce a harmonious grouping, regard must be had to the kind of effect required, whether lively, medium or sombre. In one case, bold striking contrasts will be sought, in another mild ones; and again, rejecting contrasts altogther, we may get an agreeable effect by grouping together similar or analogous colors. *Harmonies of analogy* may be produced in three ways. *First*, we may arrange the different tones of a single scale in a series, beginning with white and terminating with brown black, leaving as nearly as possible equal intervals between them. This will produce a pleasing result. The greater the number of tones the finer will be the effect. *Second*, we may associate together the hues of adjacent scales, all of the same tone, and often produce an agreeable analogy. But sometimes colors of near scales mutually injure each other, as blue and violet; the complementary of blue, which is orange, being thrown upon violet gives it a faded and blackened appearance; while the complementary of violet, which is yellow, falling upon blue turns it to green. Sometimes when one color is injured we may sacrifice it to give prominence or relief to another. *Third*, a pleasing harmony of analogy is produced by viewing groupings of various colors through a colored medium that casts

its own peculiar hue over the whole, as when we view a carpet in light that comes through a stained glass window.

178. **Circumstances which disturb the influence of Colors.**—Various conditions exert a modifying effect upon the mutual action of colors The result may be greatly influenced by the shape of the object, and the manner of its exposure to light. The surface of a red curtain, for example, hung in folds, appears of different hues, the parts most exposed to the light being changed in the direction of scarlet, while those more protected from it are shaded so as to approach a crimson. The condition of surfaces is also important. When they are glossy their colors affect each other much less, and a bad association may be concealed or overlooked where the elegance of symmetry of the object, or the light and shade are so related, or our ideas are in some way so associated with it as to draw the attention from the ill effects of the colors. It is often thus that flowers present bad associations, yet our feeling concerning them is such that we are not offended as when we see the same upon flat unglossed surfaces. The flower of the sweet pea, for instance, gives us the alliance of red and violet, which mutually injure each other, though the green leaves set off the red and help the result.

179. **Effect of associating Colors with White.**—All colors appear brighter and deeper when associated with white, because its superior brilliancy renders the eye insensible to the white light which accompanies and weakens the color. At the same time the white is tarnished by the complementary of the color falling upon it. White is so intense that in all its arrangements with color, except perhaps light tones of yellow, there will be contrast. It may often be interposed with advantage between colors which injure each other. All the prismatic colors gain by grouping them with white, but not in an equal degree, for the height of tone of the color makes a decided difference in the result. The deep tones of blue, red, green, and violet, contrast too strongly with white, while the light tones of the same colors form with it the pleasantest contrasts we can obtain. Orange, the most brilliant of the colors, is almost too intense with white, while the deeper tones of yellow appear well with it.

180. **Effect of associating Colors with Black and Gray.**—Black is agreeable if associated with almost any color. With their light tones it contrasts well, making them appear lighter, and being itself darkened, while their sombre complementaries thrown upon the black scarcely affect it as its surface reflects so feebly. With the deep tones of the scales it forms harmonies of analogy, although their luminous com-

plementaries, especially those of blue and violet when falling upon black, deprive it of its vigor, and tend to make it look faded. Gray being intermediate between black and white, it is used where white gives too strong a contrast, and black makes the combination too sombre, as with orange and violet, green and blue, green and violet.

VI.—PRACTICAL SUGGESTIONS IN COMBINING COLORS.

181. **Articles of Dress.**—A recollection of the foregoing principles may enable us to avoid gross errors in combining colors. Thus a lady would hardly trim a violet bonnet with blue flowers, or an orange with yellow ribbon, while she would do well to trim a yellow bonnet with violet or blue, and a green one with rose-red or white, and to follow the same general rule in arranging the colors of a dress. We are not to overlook the effect of contrast of tone as well as color. A black coat that is much worn, will appear well in summer in contrast with white pantaloons; but if put on over new black pants, it will appear older, rustier, and more threadbare than it really is. Stains upon garments are less apparent where there is considerable difference among the colors of the various articles of apparel, than where they are more uniform, the contrast among the colors rendering that between the stain and the surrounding cloth less conspicuous. Colored articles of dress produce a deceptive effect in reference to the size of the wearer. The influence of dark or black colors is to make the person wearing them seem smaller, while white or light dresses causes the figure to appear larger than the real size. Large figures or patterns upon dresses and horizontal stripes make the person look short, while narrow vertical stripes on a dress cause the wearer to seem taller.

182. **Influence of Colors upon the Complexion.**—Any colored objects, as bonnet trimmings or draperies, in the vicinity of the countenance, change its color; but clearly to trace that change we must know what the cast of complexion is. This varies infinitely, but we recognize two general sorts, light and dark, or *blonde* and *brunette*. In the blondes or fair-complexioned the color of the hair is a mixture of red, yellow, and brown, resulting in a pale orange brown. The skin is lighter, containing little orange, but with variable tinges of light red. The blue eye of the blonde is complementary to the orange of the hair. In brunettes the hair is black, and the skin dark, or of an orange tint. The red of the brunette is deeper or less rosy than that of the blonde. Now the same colors affect these two styles of complexion very differently. A green setting in bonnet or dress throws

its complement of red upon the face. If the complexion be pale and deficient in ruddy freshness, or admits of having its rose-tint a little heightened, the green will improve it, though it should be delicate in order to preserve harmony of tone. But green changes the orange hue of the brunette into a disagreeable brick-red. If any green at all be used, in such case it should be dark. For the orange complexion of brunette the best color is yellow. Its complementary, violet, neutralizes the yellow of the orange and leaves the red, thus increasing the freshness of the complexion. If the skin be more yellow than orange, the complementary violet falling upon it changes it to a dull pallid white. Blue imparts its complementary orange, which improves the yellow hair of the blondes, and enriches white complexions and light flesh tints. Blue is therefore the standard color for a blonde, as yellow is for a brunette. But blue injures the brunette by deepening the orange, which was before too deep. Violet yellows the skin, and is inadmissible except where its tone is so deep as to whiten the complexion by contrast. Rose-red, by throwing green upon the complexion, impairs its freshness. Red is objectionable, unless it be sufficiently dark to whiten the face by contrast of tone. Orange makes light complexions blue, yellow ones green, and whitens the brunette. White, if without lustre, has a pleasant effect with light complexions; but dark or bad complexions are made worse by its strong contrast. Fluted laces are not liable to this objection, for they reflect the light in such a way as to produce the same effect as gray. Black adjacent to the countenance makes it lighter.

183. **Arrangement of Flowers in a Bouquet.**—In grouping flowers, complementary colors as far as possible should be placed side by side, blue with orange, yellow with violet-red, and rose with the green leaves. On the contrary we should avoid combining pink with scarlet or crimson; orange with orange-yellow; yellow with greenish-yellow; blue with violet or violet-blue; red with orange, or pink with violet. If these are to be inserted in the same nosegay, white should be interposed between them, as it prevents colors from acting injuriously upon each other while it heightens their tone.

184. **Best colors for Paper Hangings.**—Dark paper for the walls is bad, because it absorbs too much light, and the room is not sufficiently luminous: this is especially true of rooms with a northern aspect where the sun never enters, for such apartments paper of the lightest tints should be used. We have seen that the complementaries of red and violet are bad for the complexion (181), red and violet are therefore objectionable as wall colors. Orange and orange yellow are

fatiguing to the eye. Among the simple colors light blue, light green (314), and yellow, seem fittest for hangings. Yellow is lively, and accords well with dark furniture and brunette complexions, but it hardly appears well with gilding. Light green is favorable to pale skins, deficient in rose, and suits with mahogany furniture. Light blue goes well with mahogany, is excellent with gilding, and improves blonde complexions. White and light gray, with velvet patterns the same color as the ground, are well adapted to a wall to be decorated with pictures. In selecting a *border* we should seek for contrast, so that it may appear, as it were, detached from the hangings with which it is associated. If there is a double border, an interior one of flowers and an exterior one, the last must be deep in color and much smaller. Yellow hangings should be bordered with violet and blue mixed with white. Green will take any hue of red as a border. White hangings should have orange and yellow. Gray uniform hangings admit of borders of all colors, but no strong contrasts of tone; gilt borders do well with them. If the gray be colored, the border should be complementary. The neutral tints of paper, drabs, stones, &c., are particularly appropriate for picture-galleries,—they produce good effects in other rooms with well chosen borders and mouldings.

185. **Pictures, Frames, and Gilding.**—As the picture itself is the valuable object upon which we wish to fix attention, it is not in good taste to divert or distract it by gaudy and conspicuous surroundings and ornaments; hence simple framings, just enough to isolate or separate the picture, are preferable. Gilt frames will do with large oil-pictures, particularly if there is no gilding represented in the picture. Gilt frames also answer well for black engravings and lithographs, but a little margin of white should be left around the subject. Black frames, by their strong contrast of tone, tend to lighten the aspect of the picture, and often spoil a good engraving by taking the vigor from its dark colors. Gray frames are good, especially if the picture have a leading color, and the gray be slightly tinged with its complementary. As a rule, neither the frame nor the border within it should ever be suffered by their brightness, color, or ornaments, to injure the colors, shadows, or lights of the picture. The best ground for gilt ornaments is blue, because its complementary intensifies the color of the ornaments; hence shrewd shopkeepers who sell gilt articles line their showcases with blue. A bright green ground reddens and improves gilt objects. Red and orange pervert the gilt tint, and black lightens and weakens it (144).

186. **Assortment of Colors for Furniture.**—In determining the colors

to be used in furnishing a room, the amount of light is an important consideration; dark colors, as dark blue, crimson, &c., require much light to be seen distinctly. Red curtains redden the transmitted light of day, and impart this color to the countenances it falls upon. But by artificial or reflected light, red curtains and furniture dispose the eye to see green in the countenances of people in the room, while green curtains make the countenances rosy. Chairs and sofas, when complementary to the paper upon the wall, are most favorable to distinct vision; but for collective effect, when we desire to present the room as a unit, bold and complementary contrasts are inadmissible, as they fix the attention too much upon distinct and separate objects. It is better, therefore, in arranging for chairs and hangings to seek contrast of scales, or hues and harmonies of analogy. In trimming chairs and sofas, vivid reds should never be used with mahogany, for they are so bright that the mahogany loses its beauty, and looks no better than oak or black walnut. Crimson velvet is often used with mahogany because of its durability; but the colors are so nearly allied, that a strip of green or black galloon should be used as a border to the stuff, or a narrow cord of golden yellow with gilt nails. Green or green grays are best suited to trim mahogany and red-colored woods. In using differently colored woods we can assort the colors of their trimmings according to the rule previously laid down. The *carpet* should be selected with reference to the other furniture of the room. If mahogany is used, the carpet should not have a predominance of red, scarlet, or orange in it. If the furniture exhibit various and vivid colors, the pattern of the carpet should be simple and sober, as green and black for example, while if the furniture is plain the carpet may be gay.

VII.—PRODUCTION OF ARTIFICIAL LIGHT.

1. The Chemistry of Illumination.

187. **Natural and Artificial Light.**—As respects its sources, light is of two kinds, *natural* light, or that which comes from the sun, moon and stars; and *artificial* light, or that which man obtains at will by various means. Artificial light may be procured by electricity, galvanism, and phosphorescence; but the ordinary method is by that kind of chemical action which is termed *combustion*, the nature of which has been explained when speaking of heat.

188. **Light emitted by ignited Bodies.**—All solid substances shine when sufficiently heated. The temperature at which they become

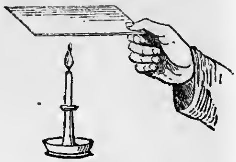
luminous, according to Dr. Draper, who has lately investigated the subject, is 977° F. He enclosed a number of different substances with a mass of platinum in a gun barrel; upon heating and looking down the tube, he saw that they all commenced to shine at the same moment, and this, even though, as in the case of lead, the melted condition had been assumed. The *color* of light emitted from ignited substances was found to depend upon the degree to which they were heated. Dr. Draper showed that as the temperature rises, the colored rays appear in the order of their refrangibility, first red, then orange, yellow, green, blue, indigo and violet, are emitted in succession. At 2130° all these colors are produced, and from their commixture the substance appears *white-hot*. The same Investigator also found, that as the temperature of an ignited solid rises, the intensity of the light increases very rapidly; platinum at 2600° emitting almost forty times as much light as at 1900°.

189. **All our illumination comes from burning Gas.**—The foregoing experiments were made upon solid substances, but their results do not hold true for gases. These require to be heated to a much higher temperature before beginning to shine; and when they do become luminous they emit but a feeble light. If we hold a piece of fine iron wire in the hot air which streams up above a lamp flame it will quickly become red, showing that a degree of heat which makes the metal shine does not make the air luminous. And yet all ordinary illumination comes from the combustion of gases. We use those materials for lighting, which in burning produce flame; and flame is burning gas. All substances which can be used for light must be capable of conversion into the gaseous state. The process is essentially the same, whether we burn the illuminating gas which is brought to our dwellings in underground pipes, or the liquid oil, or solid spermaceti. In the first instance the gas is manufactured on a large scale from solid bituminous coal or resin; in the latter cases the liquid oil and solid tallow or wax are converted into gas *at the time of burning*. In all cases the light proceeds from a rising stream of gaseous matter which is lighter than the air, and therefore tends to ascend.

190. **What takes place in the Luminous Flame.**—The materials used for illumination contain hydrogen and carbon, and the gas they yield consists of these elements more or less pure. Hydrogen, as we have before stated, is the lightest and most ethereal of all substances (76). The gas which gives rise to flame in illumination is therefore compound—a hydro-carbon. In burning, the oxygen of the air combines with these two elements, but it is not attracted to them equally. It

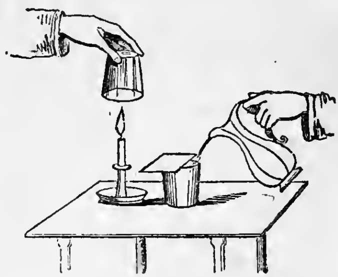
seizes upon the hydrogen first, burning it with an intense heat, and the production of water. As the hydrogen combines with oxygen, it abandons the carbon, which is thus set free in a pure state. Now pure carbon is always a solid. As the hydrogen leaves it, therefore, it is set free in the form of exceedingly minute solid particles in the midst of the heated space,—those heated to redness, yellowness, or whiteness, become luminous, and are the real sources of the light. The carbon particles remain suspended in the flame but for an instant; they are themselves quickly burned and converted into carbonic acid.*

FIG. 46.



191. **How these facts may be shown.**—If we hold a piece of clean cold glass a short distance above a candle flame (Fig. 46), a fine dew will be seen deposited upon it, which is the water generated within the flame. If a piece of white earthen be lowered over the flame the combustion is interrupted, and the unconsumed particles of carbon are deposited upon the white surface, thus proving that they exist free in the flame. If an inverted tumbler be held above a flame, so that the rising current may enter it (Fig. 47), and then it be closed with a card, set down, and a little clear lime-water poured into it and shaken, it will become milky from the combination of the carbonic acid with the lime, which shows that the former substance was generated within the flame.

FIG. 47.



192. **Admirable simplicity of the Laws of Illumination.**—There is a wonderful simplicity and beauty in this chemistry of illumination. The same active principle of the air which animates the living body and nourishes the fires which warm us, is also the awakener of light. All artificial illumination that we employ is due to the chemical energy of oxygen gas. The hydro-carbon compounds, upon which oxygen acts, are not only universal as life itself, being produced in all kinds

* See the author's Atlas of Chemistry and Chemical Chart of Colored Diagrams, illustrating combustion and illumination.

of plants and animals, but the very crust of the globe is stored with endless accumulations of them. The hydrogen combines with and condenses a much larger amount of oxygen than any other element, and consequently produces a great heat. But the burning of these pure gases, although the heat is so high, hardly creates a perceptible light. To get illumination, solid matter is required. Accordingly the lightest and most subtle of all gases, hydrogen, is associated with carbon, the most refractory of all solids, which remains fixed without melting or vaporizing at the intensest heat which art can produce. These carbon atoms are set free, and shining brilliantly for an instant pass to the verge of the flame, and there unite with atmospheric oxygen, forming carbonic acid gas. The two products of combustion—vapor of water and carbonic acid—are both entirely transparent and invisible, so that although constantly formed within and around the flame, they do not eclipse or obscure it, but let the light pass freely in all directions. If oxygen were equally attracted to hydrogen and carbon, so as to burn them both at once, no solid particles would be liberated in the flame, and consequently there could be no light. It is the *successive* combustion which takes place,—first the hydrogen burning and then the carbon, which gives rise to the luminous effect.

193. **Threefold form of Illuminating Substances.**—The modes of burning illuminating materials are various, depending upon their forms and properties. If capable of being used in a solid condition, they are moulded into a cylindrical or rod-like shape, and are called *candles.* If liquid, they are consumed from suitable vessels known as *lamps;* and if gases, they are simply jetted from minute orifices, by pressure upon the gaseous fountains. There are several things with respect to each of those methods of illumination which it is important to understand.

2. Illumination by means of Solids.

194. **Adaptation of Tallow for Candles.**—Those fatty and waxy bodies, which are sufficiently hard and solid to be handled, are worked into candles. They are made from tallow, stearine, spermaceti, and wax. There has been no way devised for burning those softer, fatty and greasy bodies which lie between the liquid oils and these firmer substances. Tallow derived from beeves or sheep is most universally employed for candles. If they are mixed there should not be too great a proportion of mutton tallow or suet, as this contains a peculiar principle called *hircin,* which causes it sometimes to give a disagreeable smell, especially in hot weather. When of the best quality tallow

is white, firm and brittle. Alum is often put with it to harden it. The bad quality of tallow candles is chiefly owing to their adulteration with hog's fat and cheap soft grease, which makes them smell, gutter and smoke. Good tallow candles will resist decomposition for two years, and are better after being preserved six or eight months. They should be kept from the atmosphere, and may be well preserved by being covered with bran. The place for their preservation should be cool and dry, as dampness mildews and damages them. Light turns them yellow.

195. **Candles made from Stearic Acid.**—The fats and oils are believed to consist of acids combined with a base; at all events they are capable of being decomposed and separated into those substances. The common base which exists in all fats and oils is, when set free, a sweet liquid called *glycerin*. The substances combined with it are *stearic* acid, *margaric* acid, and *oleic* acid. Stearic acid, combined with glycerin, forms *stearin*. Margaric acid, with glycerin, yields *margarin;* and oleic acid, with glycerin, produces *olein*. Oleic acid, or olein, is the more liquid portion of oleaginous bodies; it predominates in the fluid oils. Stearic acid, on the contrary, abounds in the hard fats and tallows; it is their chief solidifying element. Margaric acid is less solid, being intermediate between stearic and oleic acids. The intermixture of these, in various proportions, gives rise to all the various grades of softness and solidity which the endless oil and fat tribe exhibit. Tallow contains seventy to seventy-five per cent. of stearic acid, and olive oil but twenty-five. Candles were at first made from stearin, and were much superior to tallow; but they are now manufactured from stearic acid, which is more infusible. This substance does not feel greasy to the touch, and is firm, dry, and brittle. It makes hard and brilliant candles, which are considered nearly equal to wax.

196. **Spermaceti and Wax.**—Spermaceti is a kind of stearine existing in the oil taken from cavities in the skulls of certain species of whales. It is manufactured into candles, which are of a beautiful silvery white aspect, translucent like alabaster, and having a high lustre. The wax of which bees construct their honeycomb is also used for candles. It is purified and bleached to a pure white. It burns with a clear and beautiful light, and is the most expensive material employed for illumination. Owing to its high price it is often adulterated. White lead, oxide of zinc, chalk, plaster, and other earthy bodies may be detected by boiling the wax in water, when these substances will separate and fall to the bottom. If starch or flour has been used, they

may be detected by boiling and adding a solution of iodine, which will yield a beautiful blue color, the test for starch. Yellow bees'-wax is often adulterated with resin, pea and bean meal, and many other substances. The former may be detected by the smell, and the latter by the iodine solution.

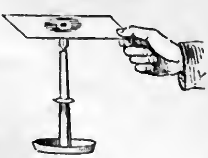
197. **Structure of Candles—Office of the Wick.**—The common burning candle affords a beautiful illustration of the general principles of illumination. If we should attempt to burn solid tallow or wax in the lamp to produce light, it would be found very difficult to set it on fire, as it would melt away long before it could ignite. But if at length made to burn, a much larger amount of the combustible would be on fire than the air would perfectly consume; there would therefore be a thick smoky flame instead of a clear white light. Some contrivance is hence needed to avoid this result and regulate the combustion, and this is secured by placing cotton fibres within the combustible, which form the *wick*. These fibres are placed parallel in the axis or centre of the candle. When the wick which protrudes at one end is set fire to, it radiates heat downwards, so as to melt the material of the candle, and form a hollow cup filled with the liquid combustible around the wick-fibres (Fig. 48). The flame is fed from this cup or cistern by the wick, which draws or sucks up the oily liquid exactly as a sponge or towel draws up water, by what is called the force of *capillary* attraction, or the attraction of small tubes for liquids. In this case the spaces between the fibres act as tubes, and attract upward the liquid fat or wax.

FIG. 48.

Flame supplied from the cistern of oil below.

198. **The burning Candle a miniature Gas-Factory.**—We thus see that the candle is a kind of lamp which constantly melts its own combustible. From the reservoir the wick draws up the liquid material to the centre of the flame. Here, in the midst of a high heat, and cut off from the air, it undergoes another change exactly as if it were enclosed and heated in the gasmaker's retort,—it is converted into gas. The candle-flame is not a solid cone of fire. If we lower a piece of wire-gauze or broken window-glass over the flame (Fig. 49), we shall see that the interior is dark, and that what we regard as the flame is really but a thin, hollow, luminous shell of fire surrounding the dark inner space. This space is filled with the hydro-carbon gas

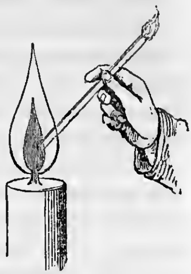
FIG. 49.



The candle-flame hollow.

manufactured from the liquid tallow, stearine, spermaceti, or wax, drawn up by the wick. This may be directly shown. If one end of a glass tube, having a bore $\frac{1}{4}$ of an inch, be introduced into a candle-flame, as seen in Fig. 50, the gas will be conveyed away through it, and may be lit at the other end, thus exhibiting a miniature gas manufactory, pipe and jet. When a candle is blown out, gaseous products of distilled and burnt tallow continue to rise, emitting a disgusting odor, and the candle may be re-lit by applying a light to the smoky stream of combustible gas which will convey the flame back to the wick. It is the hydrocarbon gas that is really burnt and produces the light, the hydrogen and carbon being successively consumed, as we have seen, at the surface, or where the air comes in contact with the gas.

Fig. 50.



The interior of the candle-flame filled with gas.

199. **Interference of the Wick with Light.**—As the candle consumes downward, the wick of course rises into the flame. In a short time it becomes so much lengthened as to interrupt the combustion and interfere with the light. Particles of unconsumed carbon are gradually deposited upon the wick, forming a large spongy snuff which nearly extinguishes the light. Peclet found that if the intensity of the light from a freshly snuffed candle be represented at 100, if left without being snuffed, its brightness is reduced in 4 minutes to 92, in 10 minutes to 41, in 20 minutes to 32, and in 40 minutes to 14, although the consumption of the candle remained the same. Rumford found that the brilliancy of an unsnuffed candle was reduced $\frac{5}{6}$ in 29 minutes. To prevent this annoyance and the necessity of frequent snuffing, wicks are sometimes so plaited and twisted, or are so slender that they bend over to the side of the flame, and coming in contact with the air are consumed (Fig. 48). This however is only practicable with the more infusible candles, stearine, wax, and spermaceti. Tallow melts so easily, that if the wick were bent over, the candle would melt down on that side and burn badly.

200. **Influence of the melting point.**—Tallow melts at 100°, spermaceti at 112°, stearine at 120°, stearic acid at 167°, and bleached wax at 155°. Candles made from those materials which are most infusible of course melt slowest; the liquid which is formed in the cup being smaller in quantity may be drawn upward to the flame with a smaller wick. Hence the wicks of wax and spermaceti candles are smaller than those used for tallow. A slender wick in a tallow candle would melt the

combustible faster than it could consume it, the liquid would overfill and overflow the cup, which takes place in what is called the *guttering* of candles. For this reason candles of softer materials require larger wicks.

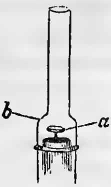
3. Illumination by means of Liquids.

201. **Argand's great Improvement.**—Lamps are vessels of various forms and appearances for burning light-producing substances in the liquid condition. They generally have wicks to feed the flame, which may be either solid round masses of fibre like those of the candle, or fibres arranged flatwise so as to produce a long thin flame, or they may be circular. Dr. Franklin showed that two small wicks placed in two candles and burnt side by side, will give more light than if they were combined and placed in one candle, as there is a greater burning surface; hence the advantage of spreading the wick-fibres out, and using them in some other form than condensed in a solid mass. Very large wicks of this kind convert the oil into gas faster than the air can completely burn it, and the consequence is that the flame smokes. To remedy this evil, the most important improvement yet made in lamps was contrived in the year 1789 by Ami Argand of Geneva, and since called after him the "Argand Burner." He made the wick hollow, so as to burn in a ring or circle, and thus admitted a current of air to the inside of the flame, by which the central core of dark unburnt gases is avoided, and a double burning surface secured. By means of sheet-iron chimneys set above the flame (which were soon replaced by those of glass), a strong upward draught of air was secured, which heightened the combustion and greatly intensified the light. The wick was raised and depressed either by means of cogwork (*rack and pinion*) or by a screw; the supply of oil is thus regulated to that of the air, and smoking prevented. An important advantage gained by the Argand burner is the great steadiness of the light caused by the chimney. When a draught of air strikes an unprotected flame, its force and cooling influence check the combustion, and produce flickering and smoke. In Argand burners, on the contrary, the supply of air is self-regulated, and the cylinder prevents any interruption of the flame by outside currents.

202. **Improvement upon the Argand Burner.**—The cylinder that Argand employed was straight, or had vertical sides. This allowed a much larger amount of air to rise within it than could take part in the combustion, and this excess had the partial effect of cooling the flame. M. Lange, a Frenchman, improved the form of the chimney-

tube, by contracting its size and constructing it with a shoulder at such a point (Fig. 51 *b*), that the rising air striking against it was deflected inward and thrown directly upon the flame. This had a powerful effect in increasing the combustion and heightening the intensity of the light. Another improvement consisted in mounting a button just above the circular opening within the burner, so that the current of air that comes up from within, will be deflected outwards, as shown in fig. 54 *a*, and thus strike directly upon the inner surface of the flame. The main point to be considered in the structure and management of lamps upon the Argand principle, or with chimneys, is the relation between the current of air and the flow of oil. This is controlled by the movable wick, the movable button, and the width and height of the chimney. As chimneys of glass only can be used, they are apt to be made large to lessen the liability to fracture, though the danger is generally overrated. As a consequence more air is conducted to the flame than is demanded for vivid combustion, while the excess, by rapidly conveying away the heat, lowers the temperature of the flame, and thus diminishes its luminous intensity. Dashing a surplus of air against the flame is also unfavorable to that *successive* combustion which is essential to illumination (192).

FIG. 51.



203. **Points to be secured in the structure of Lamps.**—Lamps are made in a great variety of ways suited to burn different kinds of oily matter, and adapted to avoid, as far as possible, certain difficulties which are incident to this mode of lighting. The distance from the burning part of the wick to the surface of the reservoir from which the oil is derived should remain unchanged, so that an equal quantity of oil may be drawn up at all times, and the reservoir should be so shaped and placed that its shadow will occasion the least inconvenience. If the wick is supplied from a reservoir below, it is obvious that just in proportion as that is exhausted, the distance from its surface to the flame is increased; the wick-fibres elevate less oil, and the light grows faint and dim. To remedy this, the reservoir in some cases is made to have a large surface of oil that will fall but little distance, although a considerable amount is withdrawn. To avoid the objectionable shade thrown by such a large cistern close to the wick, the *astral* lamp had its reservoir constructed in the form of a narrow circular vessel or ring, which threw but a small shadow. The *sinumbra* lamps had this ring so shaped and mounted as to produce still less shade. Sometimes there is a fountain of oil placed on one side higher than

the wick, with a self-acting arrangement by which the reservoir is fed from it, and its height constantly maintained at the same point. The shadow cast, in this case, upon one side, is objectionable, and limits its use to that of a study lamp (Fig. 67). In the CARCEL lamp, or *mechanical* lamp, clockwork is applied to pump up the oil through tubes in a constant stream to the wick, thus keeping it thoroughly soaked, while the excess of the oil drops back into the cistern, which is situated so far below as to cast no shade. It is moved by a spring, and wound up like a clock. It runs six or eight hours, maintaining a constant and equal flow of oil, and a bright and steady flame. These lamps are excellent, but expensive, costing from fifteen to seventy-five dollars, and requiring much care.

204. **Hot-Oil Lamps.**—One great obstacle to the use of lamps lies in the viscidity, or thickness and consequent sluggish supply of the oil to the wick; this becomes a very serious difficulty with common lamps during the winter. Dr. URE made some experiments to ascertain the relative viscidity or fluidity of different liquids, and of the same liquids at different temperatures. He introduced 2,000 water-grain measures of the liquid to be tested in a cup, and then drew it off with a glass syphon of $\frac{1}{8}$ inch bore, having the inner leg 3, and the outer one $3\frac{1}{4}$ inches long. If the weight or specific gravity of two liquids, and their consequent pressure upon the syphon were the same, their difference of viscidity would be determined by the different time they would require to flow off through the tube. He found that 2,000 grain-measures of water at 60° ran off through the syphon in 73 seconds; but when heated to 180°, they ran off in 61 seconds. Oil of turpentine and sperm oil have very nearly the same specific gravity; yet 2,000 grain-measures of oil of turpentine ran off in 95 seconds, while that quantity of sperm oil took 2,700 seconds, being in the ratio of 1 to $28\frac{1}{2}$; so that the fluidity of oil of turpentine is $28\frac{1}{2}$ times greater than that of sperm oil. Sperm oil, when heated to 265°, ran off in 300 seconds, or one-ninth of the time it took at a temperature of 64°. Hence lamps have been advantageously constructed to heat the oil before burning, either by means of a copper tube which receives heat from the flame, and conducts it downward to the reservoir, or still better by means of a cistern placed above the flame. PARKER's English Economic Lamp has its oil heated in this latter way, and is said to perform admirably.

205. **Composition of Oils.**—The oils in general use in these lamps are those derived from fish, chiefly whales, and known as sperm-oil and train-oil. Lard-oil is also much employed. . It is the more oily portion

of hogs'-fat separated by artificial means. The chemical composition of these oils is quite similar to that of the harder substances which are wrought into candles. Sperm-oil consists in 100 parts—of carbon 78, hydrogen 12, and oxygen 10; mutton tallow, of carbon 78·10, hydrogen 11·70, and oxygen 2·30; wax, of carbon 80·4, hydrogen 11·3, and oxygen 8·3.

206. **Properties of Spirits of Turpentine or Camphene.**—In addition to these substances a new class of compounds, the basis of which is derived from the turpentine of the pine tree, have latterly come into use. By distillation of the turpentine pitch, it is separated into a thin transparent liquid, spirits of turpentine or oil of turpentine, and a hard brittle residue known as common *resin*. The crude spirits of turpentine when rectified, that is, separated as completely as possible from resinous matter by repeated distillation, is burnt in lamps under the name of camphene. It differs from the substances just mentioned in its extreme liquidity (being, as we have seen, $28\frac{1}{2}$ times more fluid than sperm oil); in its powerful pungent odor, and in chemical composition, as it contains no oxygen, and consists of 88·46 parts in a hundred of carbon to 11·54 of hydrogen, and is therefore called *hydro-carbon*. Oil of turpentine is also much more highly inflammable, and is volatile and explosive.

207. **Conditions required for its Combustion.**—Oil of turpentine is a superior illuminating substance, but it contains so large a proportion of carbon, that if burned in the ordinary way, it smokes excessively. Lamps designed to burn it require to be so constructed as to supply to the flame a large and powerful draught of air, to effect the complete combustion of its elements. Camphene burns with a flame very much whiter and brighter than any of the substances we have yet noticed, and which displays the natural colors of objects, as flowers or pictures in their true tints, much more perfectly than the light of candles and oil lamps. Although more luminous, the camphene flame is smaller than the oil flame. This is explained by the fact that camphene consists entirely of carbon and hydrogen, while the fat oils contain 10 per cent. of oxygen. This oxygen, already existing in the oil, neutralizes a portion of its carbon and hydrogen, so that there is really but 85 or 86 per cent. of hydro-carbon to sustain the combustion; and not only this, but the other 15 per cent. of incombustible matter acts to hinder the combustion. On the other hand, the oil of turpentine consists of pure combustible matter, burns entirely, and contains nothing to retard the activity of the burning process. A hundred parts of fat-oil consume only 287 parts of atmospheric oxygen, while

100 parts of camphene consume 328 of oxygen. From its extreme fluidity, the oil of turpentine is also supplied copiously and constantly to the flame by the simple capillary or sucking action of the wick.

208. **Why Camphene soon spoils.**—Camphene, if exposed to the air, cannot be preserved pure. It belongs to a class of bodies known as *essential oils*, which by combination with oxygen are changed into substances of a resinous nature. Under the influence of oxygen, oil of turpentine undergoes this change, and becomes deteriorated by solid resinous impurities. When employed for illumination, therefore, it should be procured in small quantities fresh from the manufacturer.

209. **Nature and properties of Burning Fluids.**—There is another method by which oil of turpentine may be employed for illumination, which is generally much preferred, as it avoids the liability and trouble of smoke. It consists in mixing it with alcohol, so as to form what is known as *burning fluid*. Alcohol burned alone produces only a feeble bluish-white light, as it is deficient in the necessary quantity of carbon. It has the opposite defect of oil of turpentine, as that has too much carbon; the alcohol has an excess of hydrogen. By mixing them, a compound is formed which supplies the deficiencies of both, yields a good light, and may be burned in lamps of the simplest construction. These mixtures are commonly burned with wicks, but there is a lamp so made that the liquid is vaporized by the heat of the burner, and escaping in jets through minute orifices, is burned without a wick, like common illuminating gas. Owing to the large proportion of expensive alcohol which must be used in making it, and which gives but very little light, burning fluid is a very costly source of illumination (230).

210. **In what way Burning Fluids are Explosive.**—Both alcohol and oil of turpentine are very volatile; that is, when exposed to the air or not confined, they rapidly evaporate or rise into the gaseous state. In a lamp reservoir containing burning fluid, as it is gradually consumed, vapor rises from its surface and fills the upper space. In all vessels, whether lamps, cans, or jugs, if but partially filled with fluid, the remaining space is occupied with its vapor, which may or may not be mixed with air. Or when exposed to the air in open vessels, vapor rises and charges the atmosphere immediately above. Now the liquid oil of turpentine and alcohol are both infinitely more inflammable than the fat oils. These cannot be set fire to at common temperatures; they must be heated very hot before they will catch fire. But the more volatile liquids, on the contrary, will take fire at any time when exposed, though cold, and burn with great violence. But the

case is made much worse on account of the invisible vapor which they exhale. This mixes with the air, and at the approach of the slightest spark or flame, ignites explosively. When pure hydrogen is mixed with the air and ignited, it explodes with a sharp report like a pistol; the cause is the sudden combination of the hydrogen with the oxygen of the air. Now when vapor of turpentine or alcohol, or any volatile hydro-carbon is mingled with air and fired, an explosion takes place in the same way.

211. **Conditions under which Explosions occur.**—The burning fluid *itself*, although excessively inflammable, is not explosive. It does not go off like gunpowder when set on fire, nor with a sudden noise or report, such as its vapor produces. But it is always accompanied by the invisible treacherous gas which catches fire at a distance, and this ignites the fluid. Most accidents that occur with these compounds result from attempts to fill or replenish lamps while they are lit, or where there is a light near by. The vapor of the opened lamp, jug or can, is fired; it explodes with more or less violence and concussion, setting the liquid on fire, and perhaps scattering it upon the clothing of the person present, who is severely or fatally burned, while the house is very liable to be set on fire. If the lamp have a screw cap and be perfectly tight, heat may be conducted downwards from the flame through the metal, and increase the evaporation. There being no vent but through the interstices of the wick-threads, if these are close, the pressure will increase and force out the fluid and vapor so as to burn irregularly, and sometimes occasion little explosions in the flame. If the wick is loose, and the lamp be agitated so as to dash the liquid against the hot screw-cap, vapor is suddenly formed, and being pressed out the flame streams up, often producing alarm. If the pressure become too great, and there be no vent, the lamp may explode. Dr. Hays says, it is a uniform result of numerous trials connected with experiments on closed lamps, that no lamp is safe which has a closed cap, unless there are openings for the escape of vapor. It would be wise to substitute metallic lamps for those of glass, on account of the danger of fracture. When these substances are employed for light, they should not be committed to the charge of those ignorant of their properties; and it is the only safe rule, when they are used in ordinary lamps, never to open any vessel containing them when there are lights burning near by.

212. **How Burning Fluids may be used with safety—Newell's Lamps.**—The advantage which these liquids have over oils and candles in respect of simplicity, cleanliness, and greater brilliancy of light, makes

it eminently desirable that some safe way be devised to consume them. This has been done by Mr. JOHN NEWELL, by applying to them the principle of DAVY'S Safety Lamp. Hydro-carbon gases are often generated in coal mines, and when mixed with common air, are exploded by the lamp which the miners use. By surrounding these lamps with fine wire-gauze, they could be lit and carried into the dangerous mixtures without exploding them. The inside of the gauze would be filled with burning gas, but the fine wire texture has the effect of cooling the flame, so that it cannot pass through and ignite the gases outside. Hence, by ingeniously mounting his lamps with this gauze, Mr. NEWELL prevents the possibility of explosion from camphene and burning fluids. The can also for containing the fluid has a sheet of the gauze inserted under the lid, and another fixed in the spout. These do not prevent pouring; but if vapor or fluid escaping through them were lit, the flame could not enter the vessel.

FIG. 52.

Argand Lamp for Kerosene Oil.

213. **Kerosene Oil as an Illuminator.**—This is a product of the distillation of bituminous coal, and has come lately into use as a source of light. It is rich in carbon, and requires to be burned in peculiar lamps adapted to its properties It produces a bright and beautiful light, which we have used with much satisfaction. It does not vaporize, and is therefore not explosive. The proprietors make large claims on the score of its economy (230), and are entitled to credit for having prepared a variety of elegant lamps for burning it. Fig. 52 represents one of their style of parlor lamps. The cistern is narrow, and so far below the wick as to cast but little shadow. When not burning, the oil emits a kind of empyreumatic gas-odor, to which many object; but the smell is not perceived during combustion.

214. **Light from Sylvic Oil.**—This is a cheap oil from resin. It gives a vivid light, but it contains so much carbon that it is difficult to burn it without smoking; this may, however, be done with proper care in VAN BENSCHOTEN'S lamp.

4. Illumination by Gases.

215. **Conditions of the Gas Manufacture.**—The last source of illumination to be noticed is *gas*, which gives the cheapest and brightest of all the generally employed artificial lights. It has come into use entirely within the present century, and has been very widely adopted in cities. It was first employed in London in 1802, and its use has extended until 408,000 tons of coal have been consumed in a single year by the establishments of that city alone; producing four thousand millions of cubic feet of gas, and yielding an amount of light equal to that which would be produced by eight thousand millions of tallow candles, of six to the pound. How wonderful, that sunbeams absorbed by vegetation in the primordial ages of the earth's history, and buried in its depths as vegetable fossils through immeasurable eras of time, until system upon system of slowly-formed rocks have been piled above, should come forth at last at the disenchanting beck of science, and turn the night of civilized man into day.

216. **Materials used for making it.**—Gas is chiefly produced from the bituminous varieties of coal (87), those which are rich in the pitchy elements containing hydrogen. It is also made from tar, resin, oils, fats, and wood.

217. **Products of the distillation of Coal.**—If coal is used, it is placed in tight cast-iron vessels called *retorts*, which are fixed in furnaces and heated to redness by an external fire. The high heat decomposes the enclosed coal, producing numerous gaseous and liquid compounds. The principal products of this destructive distillation are *coke*, or the solid residue of the coal, a black oily liquid known as *coal-tar;* water or steam, various compounds of *ammonia*, among others that with *sulphurous acid*, *sulphuretted hydrogen*, *carbonic acid* and *carbonic oxide*, *light carburetted hydrogen*, *heavy carburetted hydrogen* or *olefiant gas*, and a small proportion of vapor of *sulphuret of carbon.* There are also variable traces of many other substances.

218. **Purification of the Gas.**—This heterogeneous mixture is totally unfit for illuminating purposes until purified. The liquid and gaseous products, as they are set free, flow out from the retort through a tube into a receiver called the *hydraulic main*, in which the liquid products of the distillation—coal-tar and ammoniacal liquor—are to a great extent separated from the gaseous products. But being hot they still retain various matters in a vaporous state, which would be deposited and clog the pipes; these are still farther separated by passing through the condenser, which consists of iron tubes surrounded by cold water.

The gas is then passed through a mixture of lime and water (milk of lime), or through layers of damp slacked lime, which absorb the carbonic acid and sulphuretted hydrogen. It is then sometimes freely washed with water, which removes all its ammonia, when it passes into a large receiving vessel, the *gasometer*, from whence it is distributed in pipes to the places where it is to be consumed.

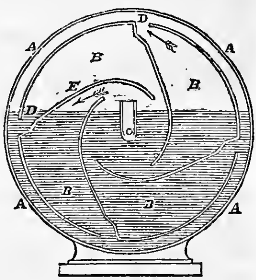
219. **Composition of Illuminating Gas.**—This is very variable, but it mainly consists of olefiant gas, light carburetted hydrogen, carbonic oxide, with free nitrogen and hydrogen, and sometimes other substances in small amounts. It takes its value from the proportion of olefiant gas which it contains, as this is the chief light-producing compound. Olefiant gas consists of 86·21 per cent. carbon to 14·79 per cent. hydrogen. Several other substances which burn with much light are liable to be associated with olefiant gas, as Butylene, Propylene, vapor of Benzole and Naphtha. Olefiant gas burns with a white and remarkably luminous flame; but it would hardly answer to burn it alone, as its proportion of carbon is so large, that if the combustion were at all imperfect, there would be liability to smoke. Light carburetted hydrogen is the same as the marsh gas, which is generated in the organic mud of stagnant pools, and rises upward in bubbles. It contains less carbon, and is richer in hydrogen; its composition being 75 per cent. of the former to 25 of the latter. It burns with a dim yellow flame, giving but little light. Carbonic oxide and hydrogen both burn with a faint blue, hardly luminous flame. Nitrogen takes no part in the burning process, except to hinder it by diluting the gas, an effect which is also produced by both carbonic, oxide, and hydrogen. The gas that comes off from a charge of good coals consists, when the retort is first raised to a vivid cherry-red heat, of 13 per cent. of olefiant gas, 82·5 carburetted hydrogen, 3·2 carbonic oxide, and 1·3 of nitrogen. After five hours the gas that continued to escape gave 7 per cent. of olefiant gas, 56 of carburetted hydrogen, 11 of carbonic oxide, 21·3 of hydrogen, and 4·7 of nitrogen. Towards the end of the operation, or after about ten hours, it contained 20 parts of carburetted hydrogen, 10 parts of carbonic oxide, 60 of hydrogen, and 10 of nitrogen. The best gas therefore is that which is produced first.

220. **Gas derived from other sources.**—Crude and refuse oil, which is unfit for burning, is sometimes converted into gas. It is made to trickle into a retort, containing fragments of coke or bricks heated to redness. The oil, as it falls upon these fragments, is instantly decomposed and changed to gas. It contains no sulphur products, and needs no purification. It is very rich in olefiant gas, and has double the

illuminating power of the best coal gas, and treble that of ordinary coal gas. Resin also, by being melted and treated in a similar way, yields a highly illuminating gas. But in point of economy, neither oil nor resin can compete with coal as a source of light. A pound of coal yields from three to four cubic feet of gas; a pound of oil, 15 cubic feet; of tar, 12; and of resin, 10.

221. **How Gas is measured.**—Gas is sold by the cubic foot, or by the thousand cubic feet. From the underground pipes (*mains*) that run through the street, a pipe branches off leading to the dwelling to be illuminated. Before being distributed through the house the gas is made to pass through a self-acting instrument called a *meter*, which both measures and records the quantity consumed in a dwelling. The meter consists of an outer stationary cylindrical case, enclosing an inner and smaller cylinder which revolves upon its axis. Both cylinders are closed at the ends, water-tight and gas-tight. The inner one is divided into four compartments with crooked partitions, and the gaspipe passes into its centre or axis, and, turning up at the end, delivers to them its contents successively. The meter is kept about two-thirds filled with water, which the gas constantly displaces as the cylinder turns. The principle will be understood by the aid of the diagram (Fig. 53), which exhibits the meter as if seen endwise, with the ends of the drums removed. *A A A A* is the outer cylinder; *B B B B* the four compartments of the inner one; *c* is the gaspipe supplying one of the apartments. As it enters the partition *E* rises, and the water passes out at the slit *D*, into the space between the two cylinders. The internal one revolves from left to right, the gas passing in the direction of the arrows, first displacing the water and filling the compartments, and then passing out into the space between the two drums, where it is conveyed away by a tube not shown in the figure. The revolving drum is connected with clockwork, which shows by an index the number of revolutions made, and the capacity of the compartments being known, the quantity of gas which passes through is correctly determined. The meter reports the amount of gas that actually passes through it; but its indications are by no means to be taken as infallible proofs of honesty on the part of the gas company. *Their* tempta-

Fig. 53.



Meter for measuring the flow of Gas.

tion is, to put on pressure and crowd more gas through than is necessary, or than can be burned with economy, for increased consumption of gas does not at all involve a corresponding increase of light (222). Nor do meters afford any indication whatever in reference to the *quality* of the gas; the companies control this, and may do quite as they please, the customer being unprotected. We do not intimate, however, that the gas-companies ever yield to the evil temptations with which they are beset.

222. **How Gas is burned.**—From the fountain of distribution—the *gasometer*—the gas flows away through the branching system of tubes under the influence of pressure. When little openings are made in the pipes, this pressure drives out the gas in jets or streams, and it is these which produce the light when ignited. The orifices are from $\frac{1}{25}$th to the $\frac{1}{50}$th of an inch in diameter. Recent experiments by the French tend to show that wider openings are more economical with the best kinds of gas. The openings are made in various ways. A circle of them round a large central orifice forms an Argand burner (201). Two holes drilled obliquely, so that the flames cross each other, produce what is called a *swallow-tail* jet. A slit gives a continuous sheet of flame, called a *bat-wing* jet. Other figures are also produced, as the "*fan-jet*," "*fish-tail jet*," &c. The quality of light depends much upon the mode of burning as well as the composition of the gas; a good article may be spoiled by mismanagement. Its illuminating power is impaired when burned too rapidly to allow the separation and ignition of the carbon particles (190). The *order* of the combustion, upon which all illumination depends, is destroyed, by excess of air, as when we move a lighted candle rapidly through the atmosphere, the hydrogen and carbon are both burned *at once*, and we get only a feeble blue flame. This occurs when gas issues with considerable velocity from a minute orifice, and by expansion gets intimately mixed with a large proportion of air. When the current of gas does not ignite at a considerable distance (several lines) from the aperture, and then burns with a faint blue flame, the gas-stream is too rapid, it is improperly mingled with the air and consumes wastefully,—that is, *to the buyer*. If chimneys are used, and the draught becomes too strong, for the same reason the light almost vanishes, yielding only a dull blue flame. On the other hand, too small a draught of air is equally injurious, not only from incomplete combustion which causes the flame to smoke, but also because the highest illuminating power of the flame is obtained only when the carbon atoms are heated *to whiteness*, which requires a considerable amount of air. We have

before seen how rapidly light is evolved by the addition of small quantities of heat at high temperatures (188).

223. **Influence of the length of the Flame.**—The dimensions of the gas-flame may be controlled with perfect facility by simply turning a stop-cock, although its extent depends upon the width of the orifice and the amount of pressure. It was found that if the light from a flame 2 inches long were represented at 100, at 3 inches it became 109, at 4 inches 131, at 5 inches 150, at 6 inches 160, *with an equal consumption of gas in each case.*

224. **How much, Gas-burning contaminates the Air.**—The active source of light in this kind of illumination, as has been stated, is olefiant gas and other compounds abounding in carbon. But these could not be burned alone even if it were possible to procure them. A diluting material is therefore necessary to give the flame sufficient bulk, and separate the particles of carbon so far asunder as to prevent the risk of imperfect combustion and smoke. Now the three substances found in gas—light carburetted hydrogen, carbonic oxide, and free hydrogen—are all equally well adapted for this purpose. So far as *light* is concerned, it is of little consequence which of these is associated with the olefiant gas. But in other respects this becomes a matter of importance. The two objections most commonly urged against the use of gas in our apartments are, *first*, the heat which it communicates to the air; and, *second*, the contamination of it by carbonic acid. Now, in these particulars, the three diluting substances have very different influences. One cubic foot of light carburetted hydrogen consumes in its combustion two cubic feet of oxygen, and generates one cubic foot of carbonic acid,—a portion of the oxygen being consumed in the formation of water with hydrogen. This produces a sufficient amount of heat, according to Dr. Frankland, to raise 2,500 feet of air from 60° to 80·8°, while a cubic foot of hydrogen burned under the same circumstances produces *no* carbonic acid, and yields heat capable of raising 2,500 cubic feet of air 60° to 66·4°. One cubic foot of carbonic oxide consumes in burning half a cubic foot of oxygen, and generates one cubic foot of carbonic acid. The light carburetted hydrogen, therefore, is the worst diluent and hydrogen the best, as it produces no carbonic acid, and excites least heat. We saw that at different stages of heating, the coals in the retort yielded at one time a gas, rich in illuminating constituents, and at another time a gas deficient in these, but rich in hydrogen (216). Advantage has been taken of this fact to mingle the products of the retorts at different stages of heating, by which the olefiant gas is diluted with hydrogen, and a mixture

produced of superior illuminating qualities and the least injurious effects.

225. **Disadvantages of Gas-lighting.**—The chief obstacle to the use of gas-lights in private houses is, that the burners are stationary, and cannot be placed in positions available for all purposes. Candles and lamps are movable, but a gas-light, even where flexible india-rubber tubes are used, is more or less a fixture. The burners being usually situated high for general illumination, and calculated for giving more light than is required for one or two persons, cannot be reduced to the limits of the strictest economy of consumption. Hence, although gas is the cheapest of all sources of illumination, this apparent necessity for consuming it in large quantities prevents the real saving that might otherwise be expected. We have just spoken of the effects of burning gas upon the air, and shall notice it again, as also the prejudices against its use (275).

226. **Care of Gas-fixtures.**—Air, when mixed with gas, exerts upon it a slow change, tending to produce fluid and solid bituminous bodies by oxidation. Now if air gets access to the tubes and mingles with the gas, as it does constantly between the burner and the stop-cock, when the gas is not burning, the pipe becomes coated and obstructed, and hence requires periodical cleaning, which should be done with instruments that ought to be furnished gratuitously by the gas companies. Gas of high value contains six per cent. of its volume in vapor, which can become fluid in the pipes when they are exposed to the temperature of freezing water. Hence depressions in the pipes soon collect fluids, unless they decline *towards* instead of *from* the meter, and the flow of gas to the burner is irregular, producing fluctuation or what is called 'jumping' of the flame. When the burners are long out of use, as sometimes in summer, the pipes are liable to become deranged and clogged, and as gas acts on and solidifies all oily and lubricating substances hitherto used, the keys of stop-cocks often become fixed.—HAYS. The ventilation of gas-burners will be described when treating of air (360).

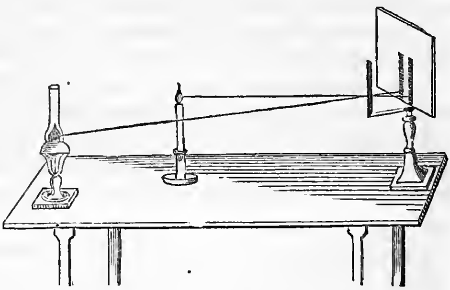
5. MEASUREMENT OF LIGHT.

227. **Can Light be Measured?**—It is sometimes of importance to determine the cost of light produced in different ways and from different materials. There is no method known by which light can be *directly* measured; that is, we have no mode of estimating the absolute quantity of light emitted by a flame, but we can ascertain how much more

or less light one flame produces than another, and thus arrive at useful *comparative* results. All flames are not equally bright,—of two flames of equal size, one may be much more brilliant and emit more light than the other. We do not judge of the intensities of different lights by direct comparison, but by the comparison of their shadows, on the principle that the greater the illuminating power of the light the deeper is the shadow which it casts.

228. **How Light is Measured.**—Before a piece of board, covered with unglazed white paper at a distance of two or three inches, let an iron rod be placed which has been previously blackened by holding it in the candle. Now if it is desired to compare two lights, they are to be placed opposite the board at the same height, and each will cast a shadow upon the paper as illustrated in Fig. 54. The lights should be so situated that the shadows will fall close to each other, and the stronger flame should be so far removed, or the weaker advanced, that both shadows will appear equally deep. To ascertain their luminous intensities we measure the difference from their centres to the shadow: if these are equal, their illuminating powers are equal; but if one casts an equal shadow at a greater distance than the other, its light must be more intense, or its illuminating power greater. The difference in the degrees of light is not proportional to the distances of the luminaries from their shadows, but to the *squares* of these distances, in accordance with the law of radiation before explained (136). If one light at two feet, and another at six, give equal shadows, their difference is not as six to two, but as the square of 6, which is 36 to the square of 2, which is 4; that is, 36 to 4, or 9 to 1. The luminary at 6 feet gives nine times as much light as the one at 2 feet.

Fig. 54.



Photometer or contrivance for measuring the intensity of light.

229. **We have no unit for measuring Light.**—This plan, modified in various ways, affords a ready means of comparing the relative amount of light emitted by two flames. But we have not been able yet to reap the practical advantages which this success at first appears to promise. If we can measure light, why not establish the exact illumi-

nating values of the various lighting materials, so that we may know precisely how far a dollar will go in buying light when the substances are at given prices. Something has been done in this way, but we have no results that command implicit trust. The composition of the materials is variable, and the same materials in different trials give different results. We are without an accepted unit to serve as a standard for a scale of values. It has been proposed to make the spermaceti candle (6 to the lb.), burning 120 grains to the hour, the unit of measure. If this were satisfactory, we could compare other lighting materials with it. A burner consuming a certain amount of gas per hour would equal a given number of candles, and any variation in its quality would be easily detected. We should speak of it as 10 candle-gas, 15 candle-gas, and 20 candle-gas, according to its grade, and so of the various illuminating substances. But these candles have been found to burn variably, and do not perfectly answer. Some unit will probably be fixed upon by which the comparative values of lighting materials may be determined and expressed.

230. **Photometric Results of Ure and Kent.**—Dr. Ure gives the following as the cost of an equal amount of light per hour from several sources, according to his experiments.

	Pence.
Carcel Lamp, with Sperm Oil	1¼
Wax Candles	6
Spermaceti Candles	5¼
Stearic Acid Candles	4¼
Moulded Tallow Candles	2½

E. N. Kent, of the U. S. Assay Office, experimented on various lighting materials with the following results:

Materials.	Lamp used.	Retail price of Oil per gallon.	Cost of an equal amount of light.
Kerosene Oil	Kerosene	$1 00	$4 10
Camphene	Camphene	63	4 85
Sylvic Oil	Rosin Oil	50	6 05
Rape Seed Oil	Mechanical	1 50	9 00
Whale Oil	Solar	1 00	12 00
Lard Oil	Solar	1 25	17 00
Sperm Oil	Solar	2 25	26 00
Burning Fluid	Large Wick	87	29 00

VIII.—STRUCTURE AND OPTICAL POWERS OF THE EYE.

231. **Value of the sense of Vision.**—The eye is perhaps the most important organ of sense. By it the mind is put into the widest communication with the external world. Although it may be said that this organ only recognizes light and colors, yet through it we become acquainted with the forms, magnitudes, motions, distances, directions and positions of all objects, whether immediately around us, or re-

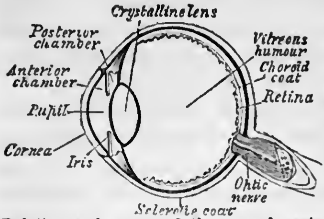
motely distributed through the distant universe. In its adaptation to the agent which is designed to act upon it, the eye is a miracle of beauty and wise design. For this reason alone we might well afford to devote a little space to it; but when we consider that it is an organ of exquisite delicacy, and greatly liable to abuse from the domestic mismanagement of light, as well as other causes, and remember how tedious and distressing are its disorders, and what a lamentable life-disaster is its loss, it becomes of the first importance to assist in diffusing any suggestions that may lead to its better care. Our previous study of light and colors will moreover aid us materially in forming correct ideas upon the subject.

232. **Sclerotic Coat and Cornea, and their uses.**—When the eye is removed from its socket and dissected, it is found to consist of several coats. The outer one forms the *white of the eye;* it is a tough, resisting membrane, and serves both to sustain the delicate parts within, and also to give insertion to those outer muscles which roll the eye-ball. It is called the *sclerotic coat*, or briefly *the sclerotic.* As light is to enter the eye, and as, from the nature of the organ, it could not be admitted through a hole, it became necessary to have a window in the eye-ball. In the front part of the globe there is a circular opening in the sclerotic, which is closed by a thin and perfectly transparent membrane called the *cornea*, the front window of the structure. The cornea bulges out somewhat like a watch-glass; that is, it is more convex than the general surface of the eye-ball, as may be felt through the closed lid. It covers that portion of the eye which is colored, and is attached round the edge of the colored part to the sclerotic coat, with which it is continuous. The cornea is very hard, tough and horn-like, the word being derived from the Latin *cornu*, which signifies *horn.* The general arrangement of the parts we are describing is shown in the accompanying view of the section of the eye (Fig. 55).

233. **The Iris and Pupil, and their uses.**—Behind the cornea there is a small space or chamber filled with a perfectly clear and colorless liquid, which consists chiefly of pure water, and is called the *aqueous humor.* This chamber is divided by a thin partition known as the *iris*, in the centre of which there is a circular aperture called the pupil. The pupil is simply, therefore, a hole through the iris; it is the round black spot which we see surrounded by a colored ring. That colored ring is the iris. It is black behind, and on the front or visible side, it is of different colors in different individuals. The color of the iris is observed to be, in some measure, connected with the color of the hair. The iris has the remarkable property of con-

tracting and dilating under the influence of light, by which the pupil is enlarged and diminished. If the light be strong, the iris contracts and reduces the size of the pupil, so as to exclude a portion of the light; if the light be weak, the iris expands so that more light is admitted. This moderates and equalizes the illumination of the organ, the delicate sensibility of which might otherwise be injured. The play of this mechanism may easily be seen by bringing a candle near to the eye while gazing upon its image in a looking-glass. These movements are involuntary, the eye regulating the quantity of light it will receive, independent of the choice of the mind.

FIG. 55.



Relation and names of the several parts of the Eye.

234. **Crystalline Lens and Vitreous Humor.**—Behind the little chamber, of which we have spoken, and bounding it on the back side, is a substance in the form of a double convex lens, called the *crystalline lens.* It is situated immediately behind the pupil, very near it, is a little larger than that opening, and is very convex, its thickness being almost equal to its diameter. It is supported by a ring of muscles called the *ciliary process.* The crystalline has about the consistence of hard jelly, and is purer and more transparent than the finest rock-crystal. It is this part which becomes diseased in cataract. The space behind the crystalline lens constitutes the main body of the eyeball, and is filled with a clear gelatinous fluid, very much resembling the white of egg, and called, from its apparent similarity to melted glass, the *vitreous humor.*

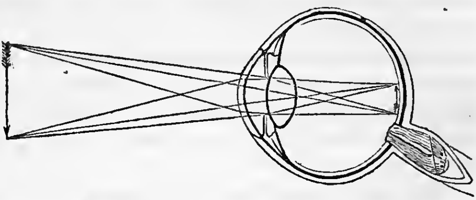
235. **The Choroid Coat, and how it is Colored.**—There is a second coat, lining the interior of the sclerotic, which consists of minute vessels, arteries, and veins, closely internetted, and is called the *choroid.* It extends around to the cornea, and supports the ciliary process. The inside of the choroid is covered with a slimy matter of an intensely black color, called the *pigmentum nigrum* (*black pigment*). This gives to the interior of the eye a jet-black surface, which absorbs and stifles the light, so as effectually to prevent reflection.

236. **Optic Nerve and Retina.**—At the back part of the eye, the sclerotic coat is formed into a tube which leads inwards to the brain. This tube contains the *optic nerve.* As it enters the globe, it spreads out over the inner surface of the choroid, in the form of a most deli-

cate network of nervous filaments, called, from its reticulated structure, the *retina*. The retina is therefore the extended and diffused optic nerve. In dissection it is easily separated from the choroid. It is absolutely transparent, so that light and colors penetrate and pass through it perfectly, and therefore fall upon the dark surface beneath. To prevent the delicate and transparent nerve tissues of the retina from being stained by the black pigment, a very thin film is interposed between them called *Jacob's membrane.*

237. **How Vision is Produced.**—From every object which we see, rays of light pass into the eye, penetrating the successive transparent media, the cornea, the aqueous humor, the crystalline lens, and the vitreous humor, and falling upon the retina, form there an image of the visible object, the impression of which is carried by the optic nerve to the brain. The diagram (Fig. 56) shows how, in the perfect eye, the image is made to fall accurately upon the retina. It is seen to be inverted. The pictures in the eye, of every thing we behold, are upside down, although there is no confusion, and we are unconscious of it. We have said that the image is formed upon the retina, and this is the common mode of expression, but that is perfectly transparent, so that the colored image is formed, not properly *upon it*, but upon the black surface of the choroid coat behind it. It is maintained that the retinal membrane is affected by the colored image in the same manner that the sense of touch is affected by external objects. It is supposed to touch or feel, as it were, the image on the choroid, and transmit the impression to the brain, something in the same way that the hand of a blind person transmits to the organ of consciousness, the form of an object which it touches. This view seems to be confirmed by the fact, that at that portion of the retina where the optic nerve enters the eyeball, which therefore has not the black choroid behind, it is insensible, and produces no perception. It has been proved by experiment that images made to fall upon that spot, are instantaneously extinguished.

FIG. 56.



How the Images are formed in the perfect Eye.

238. **Wonderful Minuteness and Distinctness of the Images.**—Nothing is more calculated to awaken our astonishment than the perfect dis-

tinctness of the pictures upon the retina, compared with their magnitude. The diameter of the picture of the full moon upon the retina is but the $\frac{1}{200}$ part of an inch, and the entire surface of the picture is less than the $\frac{1}{32000}$ part of a square inch. And yet we are able to perceive portions of the moon's disc, whose images upon the retina are no more than the 15,000,000th part of a square inch. The figure of a man 70 inches high, seen at a distance of 40 feet, produces an image upon the retina the height of which is about the $\frac{1}{14}$ part of an inch. The face of such an image is included within a circle whose diameter is about $\frac{1}{12}$ of the height, and therefore occupies on the retina a circle whose diameter is about $\frac{1}{70}$ part of an inch; nevertheless, within this circle, the eyes, nose, and lineaments are distinctly seen. The diameter of the eye is about $\frac{1}{12}$ that of the face, and therefore, though perfectly visible, does not occupy upon the retina a space exceeding the 1-4,000,000th of a square inch. If the retina be the canvas on which this exquisite miniature is delineated, how infinitely delicate must be its structure, to receive and transmit details so minute, with such wondrous precision; and if, according to the opinion of some, the perception of these details be obtained by the retina *feeling* the image formed upon the choroid, how exquisitely sensitive must be its touch. (LARDNER.)

239. **Adaptation of the Eye to Intensities of Light.**—The susceptibility of the eye under great variations of intensity in the light which enters it, is most wonderful. We can read a book either by the light of the sun or of the moon, yet sunlight is more than a quarter of a million times more brilliant than moonlight. "The direct light of the sun has been estimated to be equal to that of 5,570 wax candles of moderate size, supposed to be placed at the distance of one foot from the object. That of the moon is probably only equal to the light of one candle at a distance of twelve feet, hence the light of the sun is more than 300,000 times greater than that of the moon." Wollaston estimated the light from Sirius, one of the largest fixed stars, as twenty thousand million times less than that of the sun.

240. **Conditions of the System affect the Eye.**—The eye is thus an optical contrivance which challenges our wonder continually for the exquisite beauty and perfection of its parts. Yet we must not forget that it is a living organ of the body made up of vessels, membranes, muscles and nerves, and nourished by the vital blood-stream like any other organ. It is therefore liable to be influenced in numberless ways by conditions of the system. When in use, it *acts*, expends force, exhausts itself and becomes fatigued. Dr. WHARTON JONES remarks:

'Much exertion of the eyes operates more prejudicially to the sight under some circumstances than under others. Exertion of the sight is especially prejudicial immediately after a full meal; after the use of spirituous drinks; while smoking; when the body is in a recumbent or stooping posture, when dressed in tight clothing, especially a tight neckcloth; tight corsets; and even tight boots or shoes; in close and ill-ventilated apartments lit with gas; after bodily fatigue; during mental distress; late at night when sleepy; after a sleepless night; while the bowels are much confined; during convalescence from debilitating illness. Though during recovery from severe disease the eyes cannot bear much exertion, yet, for want of other employment, it is not uncommon for convalescents to read even more than when in health. Many persons have much injured their sight in this way. Young growing persons, at the age of puberty, persons of weakly constitutions, are incapable of supporting much exertion of the eyes without injury to the sight." Sudden suppression of the perspiratory action of the skin, or any cause which determines a pressure of blood to the head, is also liable to affect the eyes injuriously.

241. **Reading and Writing.**—In this reading age, with such strong and insidious temptations to overuse and bad management of the eyes, it may be well to make some suggestions concerning this mode of exercising vision. The closer the eye is confined to the page, the more of course it is strained. Novel reading is worse than science, history, or any grave subjects, because in the first instance we read fast and uninterruptedly, while in the latter cases thinking alternates with the use of the eyes in reading. Reading from a broad page with the lines long and the print small, is very tiresome, as it is difficult for the eye always to take up the next line. Writing down our own thoughts is easy for the sight; but copying is hard, as we have both to read and write, and look backward and forward in addition. Reading when in motion, as in riding or walking, or in the brightness of sunshine, or under a tree, where from the motion of the leaves by the wind lights and shadows fly over the page, are all severe upon the eyes, and liable to injure them. But perhaps the most serious mischief to which we are exposed in reading, comes from the bad quality of artificial light, which we shall notice particularly further on.

IX.—OPTICAL DEFECTS OF VISION—SPECTACLES.

242. **Limits of perfect Vision.**—The transparent portions of the eye, the cornea and included humors, act as lenses (149), which bend or refract the light from its straight course as it passes through them,

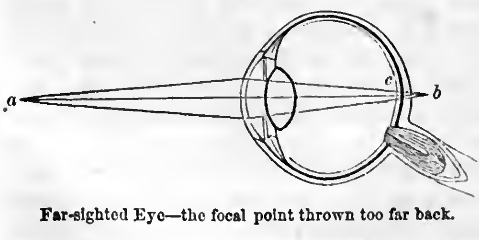
bringing it to a point or focus at the back of the eye. Where the vision is perfect, the rays are so bent that the image, in its utmost distinctness of outline and color, falls exactly upon the retina, as shown in Fig. 56. If the eye were a fixed or rigid mechanism, as if made of glass, only objects at certain precise distances would come to a point upon the retina, all others would produce their images either before or behind it, and thus give rise to imperfect vision. But the organ possesses a power of adjustment by which objects at different distances may be seen clearly. How this occurs is not understood. Perhaps the crystalline lens is capable of slightly varying in position and curvature. The limits of perfect vision in the normal eye vary somewhat in different persons; but in general they may be put down as between nine and fifteen inches.

243. **Cause of Far-sightedness.**—The eye is a system of lenses beautifully arranged to bend light to a point. But its bending or convergent powers may be too *high* or too *low*, producing imperfect vision in either case. This converging or refractive power depends upon the curvature of the lenses. The rounder they are, the stronger they are; the flatter they are, the weaker they become. As persons advance in life, there is a tendency to loss of fluids, which fill and distend the body, and a consequent shrinking of the flesh and wrinkling of the skin. The eye participates in this natural change of tissue, its contents seem to shrink, and the cornea becomes flattened or loses something of its convexity, appearing as shown in Fig. 57. This produces *far-sightedness*, in which persons can see objects distinctly only when they are at a very considerable distance from the eye, such as holding the book at arm's length in reading. In this state of the eye the rays tend to a focus at a point behind the retina, on which, therefore, they strike in a scattered state, forming an indistinct image. In

FIG. 57.

Far-sighted Eye with flattened cornea.

FIG. 58.

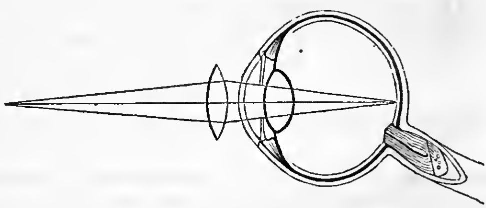


Far-sighted Eye—the focal point thrown too far back.

Fig. 58 the object *a* has its focal point thrown back to *b*, making a confused picture upon the retina at *c*. The further an object is from us, the less divergent or more parallel are the rays coming from it; and the less divergent are the rays which enter the eye, the easier are they brought to a focus by it. This is the reason that to the far-sighted, distant objects are distinct, and near ones confused. The far-sighted see minute objects indistinctly at every distance, because when near they are out of focus, and when remote from the eye, they do not reflect sufficient light to make a strong impression. They hence strive to increase the light upon the object, as we often see when attempting to read by candlelight, they place the candle between the book and the eye, and both at arm's length. It is but rarely that eyes recover naturally from this defect, yet much may be done to preserve the sight by care. When the eyes begin to fail, all over-exertion, as minute work or reading by badly arranged artificial light, should be avoided. As soon as the eyes begin to feel fatigued or hot they should have rest.

244. **How Glasses help the Far-sighted.**—The remedy for this defect is convex lenses, which are so selected and adapted to the eye as exactly to compensate for the want of refracting power in the organ itself. These lenses gather the rays to a point at various distances depending upon their curvature. The greater the curve, the nearer the focus and the higher the power; while with less curvature, and a more distant focus, there is lower power. The refractive power of a glass is expressed by the distance of its focal point in inches. A 10-inch glass, or a No. 10, collects the rays to a point at a distance of 10 inches, a No. 5 at 5 inches, and a No. 20 at 20 inches. The higher numbers express the lower powers, and the lower numbers the higher powers. Fig. 59 shows the far-sighted eye, with its internal focus, properly adjusted by a convex glass.

Fig. 59.



Far-sighted Eye corrected by double convex glasses.

245. **Management of far-sighted Eyes.**—When the sight begins to fail, and glasses are sought, those of the lowest power, which will bring objects within the desired distance, should be chosen. But they should be comfortable and not cause headache, nor strain or fatigue

the eyes; if they do this, they are too convex. If practicable, it is well to get two or three pairs from the optician, as nearly correct as possible, and try them leisurely at home before deciding which to take. If the eyes only see clearly at a *very great* distance, the No. of the glass required will be the same as the number of inches at which it is desired to read. But the moderately far-sighted do not require such strong glasses. If they can see small objects distinctly at 20 inches distance, for example, and wish to be able to read at 12, the power of the desired glass may be obtained by multiplying the two distances together, and dividing the product, 240, by the difference between them, viz. 8; the quotient, 30, is the focal length in inches of the glasses required. The intensity of the light influences the power of the glasses used; it is commonly found that those a degree more convex are required by artificial light, than by daylight. Many suppose that glasses of certain focal lengths correspond to certain ages, but no rule of this kind is safe. The nearest average relation between the age and the focal length of the convex glass is as follows:

Age in Years	40,	45,	50,	55,	60,	65,	70,	75,	80,	85,	90.
Focal Length in Inches	36,	30,	24,	20	16,	14,	12,	10,	9,	8,	7.

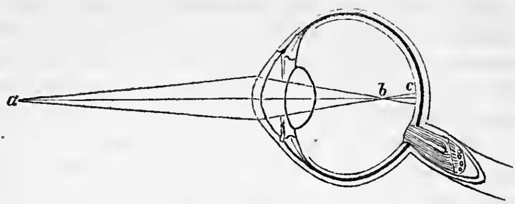
246. **Near-sightedness.**—This is the opposite defect; the cornea is too rounded and prominent, as shown in Fig. 60. The rays of light which fall upon it are consequently too powerfully refracted, and arriving at a focus before reaching the retina, cross, and are in a scattered state when they do fall upon it, as illustrated in Fig. 61, where *a* is the object, *b* the focus, and *c* the confused rays falling upon the retina. In this condition of vision, persons can see objects with perfect distinctness only when they are at a short distance from the eyes; if they bring minute objects closer than ten inches they are usually accounted near-sighted. By bringing the object nearer it is distinctly seen, because the rays of light from it which enter the eyes, being more divergent than when it was distant, are not so soon brought to a focus. The near-sighted eye retains its power of adjustment to distances; the nearest distance may be from 2 to 4 inches, while the greatest is from 6 to 12. Short-sighted people see minute objects more distinctly than other people, because from their nearness

Fig. 60.

Near-sighted Eye, with its Protruding Cornea.

they are viewed under a larger angle and in stronger light. They can see better than others with a weak light, and hence can read small print with a feeble illumination. To persons who are occupied with minute objects, short-sightedness, unless extreme, is rather an advantage, as they can observe all the details of their work very accurately, while for distant vision they can get ready help from glasses. Yet if an eye be at first perfect, the constant employment of it upon small objects tends to produce near-sightedness, which is hence a common defect of vision among the educated classes, and those who do much minute work. On the contrary, the habitual exercise of the eyes upon distant objects improves their power in that direction. If young persons have a tendency to nearness of sight, and are designed for vocations in which lengthened vision is required, they should avoid much exertion of the eyes on small objects, and exercise them frequently in scenes in the open country. It is an error that the near-sighted acquire perfect vision as they advance in life. We often see old people who are compelled to use near-sighted glasses; indeed, this state of the eyes sometimes occurs in old persons whose vision was previously at the usual distance.

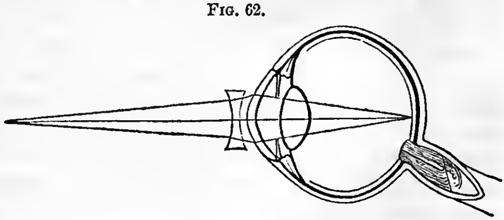
Fig. 61.



Near-sighted Eye, the focus falling too far forward.

247. **Management of Near-sightedness.**—Concave glasses extend the vision of the near-sighted by separating or diverging the rays of light before they enter the eye, so that they may be less quickly brought to a focus, and the image formed further back, as shown in Fig. 62. The powers of glasses for the near-sighted are expressed in a manner contrary to those for the far-sighted (245). They are numbered 1, 2, 3, &c., No. 1 having the

Fig. 62.



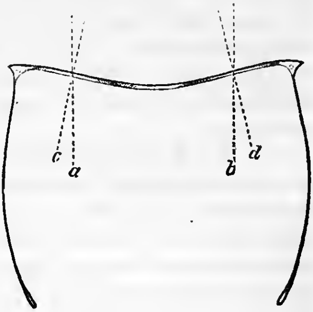
Near-sighted Eye, corrected by double concave glass.

smallest convexity and the smallest power, and being therefore adapted for those that are least near-sighted. In selecting glasses, the near-sighted should choose the lowest or weakest powers that will answer the purpose, and the best plan is to make trial of a series, as was suggested to the far-sighted. If the glasses make objects appear very bright, or glaring, or small, or produce fatigue, strain, or dizziness and confusion of vision after being laid aside, they are too concave. If glasses are wanted for reading or to behold near objects, the power of the required glass may be determined as follows: Let a person multiply the distance at which he is able to read easily with the naked eye, say four inches, by the distance at which he wishes to read, say 12 inches, and divide the product, 48, by the difference between the two, which is 8; the quotient, 6, is the focal length of the glasses required. The far-sighted have to change their glasses as the sight progressively fails, but near-sightedness usually continues much the same through the greater part of life, so that the same glass gives assistance a much longer time. It is well for both the far-sighted and near-sighted to employ glasses of various grades for different purposes. Thus the near-sighted need glasses adapted to distant objects, and as they are much inclined to stoop in reading and writing, they might remove the eye further from the page by using glasses of slight concavity. Near-sightedness may be occasioned by other causes than the one just noticed. There may be a declining sensibility of the retina, which makes it necessary to bring objects nearer to the eye; this is called *nervous short-sightedness*, and although objects are seen better close by, yet they are not seen so distinctly as in true or optical short-sightedness. Such persons seek strong light, to get a more vivid impression, and use *convex* glasses to increase the light upon the retina. This use of glasses is perilous (266). Short-sightedness is sometimes a symptom of commencing *cataract*. This disease is not, as is commonly supposed, something growing over the sight on the outside of the ball. It is a change in the crystalline lens, by which it loses its transparency, and becomes more or less opaque, so as to confuse, scatter, or stop the light, and destroy the distinctness of the image. Children often shorten their vision at school by stooping over their desks and poring over bad print, combined with the debilitating action of extreme heat and bad air, a result which should be carefully guarded against by parents and teachers.

248. **Important Suggestions in selecting Spectacles.**—Whatever be the defects of vision which spectacles are designed to remedy, there are certain points which should always be observed, both by the maker in

mounting the glasses, and by the buyer in selecting the frames. It is essential that the lenses be so framed that their axes shall be exactly parallel, so as to coincide with the axes of vision when the eyes look straight forward. Frames are often made so light and flexible as readily to bend in clasping the head, so that the glasses cease to be in the same plan, and their axes lose their parallelism. This is shown in Fig. 63, where the axes of the lenses, *c d*, instead of coinciding with the axes of vision, *a b*, are altered in their direction, and become convergent. Again, the most perfect vision with spectacles is produced when the eye looks through the centre, or in the direction of the axis of the lens. Where the eye turns from the axial centre of the glass, and looks obliquely through it, the view is less clear and perfect. For this reason persons wearing spectacles generally turn the *head*, where those without them generally turn the *eye*.

FIG. 63.



The axes of the glasses, *c d*, should coincide with the axes of vision, *a b*.

The distance between the centres of the lenses should be exactly equal to the distance between the centres of the pupils. As the clearest vision is through the centres of the glasses, the eyes will have a constant tendency to look in that direction. Hence, if the lenses be too far apart, the eyes, in striving to accommodate themselves, will acquire a tendency to an outsquint; while if the glasses are too near together, there will be, for a similar reason, a tendency to an insquint. The frames should not only correctly adjust the glasses, but should maintain them firmly and steadily before the eye. The lenses should be free from veins or small bubbles, be ground to an exact curvature, and be perfectly polished and free from flare, or what is technically called *curdling*. What are called 'pebble-glasses,' or 'pebbles,' are sometimes used; they are cut from Brazilian rock-crystal, and have the advantage of being more transparent than glass; they are also much harder, do not scratch, take a higher polish, and consequently transmit more light.

X.—INJURIOUS ACTION OF ARTIFICIAL LIGHT.

249. **Artificial Light not White, but Colored.**—Artificial light differs from daylight in composition; it is *colored*, while daylight is of a pure

white. We have seen that white light is a compound, consisting of three simple colors, red, yellow, and blue (159). There is no means of positively determining the proportion in which these colors combine to produce white, although it is commonly stated to be, red 5, yellow 3, blue 8. Whatever may be the measured quantities in which they combine, we know that any disturbance of those quantities destroys whiteness and produces a colored light. Now our common artificial lights are not really white; they appear so from want of a pure white to contrast with them. They are more or less deficient in blue, and consequently appear of the tints which result from a mixture of what remain, yellow and red; these combined produce orange, so that artificial luminaries produce in a greater or less degree yellow or orange-colored light.

250. **How the fact may be shown.**—To become assured of this fact, it is only necessary to observe both daylight and candlelight under circumstances favorable for comparison, which may be done in the following manner. If a lighted candle be placed in a box, with a round hole cut in one side so that the rays may pass through and form a luminous circle on a sheet of white paper; and if then a second luminous circle be formed on another part of the paper by a beam of daylight admitted through an opening in a closed window-shutter, the orange-yellow tint of the candlelight, contrasted with the whiteness of the other circle, will then be strikingly apparent.

251. **Order of deviation of different Lights from Whiteness.**—The red-colored light is produced by the slowest and most imperfect combustion (188); as the burning becomes intenser orange and yellow appear, and lastly, at the highest temperature, blue, which by mingling with the other colors produces whiteness. The different illuminating substances yield lights of various tints, from a dingy red up to white, according to their composition and the various circumstances of combustion which we have noticed. Dr. J. Hunter arranges the lights of illuminating substances as degenerating from whiteness nearly in the following order. Oil-gas, naphtha; sperm oil; coal-gas from the best coal; wax, spermaceti, and stearine candles; vegetable oils; moulded tallow candles; coal-gas from inferior coal; coarse oil and dipped tallow candles. Camphene and kerosene oil will probably rank with the best gas, and a good quality of burning fluid with spermaceti candles.

252. **Alteration in Colors seen by Artificial Light.**—It is well known that colors appear differently when illuminated artificially than when seen by daylight. This is a necessary consequence of the difference in the

rays which fall upon them. As sunlight contains a large proportion of *blue* rays, and artificial light an excess of *yellow* rays, they must inevitably influence the color of surfaces in a different manner. In artificial light green has a yellow hue, and blue turns green from the excess of the yellow rays; dark blue becomes purple and nearly black; orange, by reflecting its own constitutent rays, appears very bright; yellow appears white, from there being no really white light to contrast it with, and red has a tawny color from the excess of yellow; at the same time all the colors except the orange are much impaired in brilliancy, and many of the deeper shades become quite black and sombre, from there not being any pure white light reflected from their surfaces, as in daylight, when even the gravest colors have a remarkable degree of clearness and purity. Of course the appearance of colors by artificial light will depend directly upon its *quality*. The whiter and purer and nearer to daylight it is, the more bright and natural will they be; while the more colored and dingy the light, the more chromatic disturbance and perversion will it produce.

253. **How Artificial Light affects the Eyes.**—But the eye itself is affected by the use of artificial light, as is shown by the following simple experiment, suggested by Dr. James Hunter. "Tie up the left eye, and with the other look steadily and closely for about a minute at some small object placed upon a sheet of white paper, and strongly illuminated with ordinary daylight, but not exposed to the direct rays of the sun; then uncover the left eye and look at some distant white object or surface, such as the ceiling of the room, first with the left eye and then with the right. It will be found that there is not much difference in its appearance as seen by one eye or by the other, though in general it will be a very little brighter to the left eye. After this, darken the room by closing the shutters, tie up the left eye again, and then with the right one look at the same object placed on a sheet of white paper as formerly, but illuminated by a large tallow candle or oil lamp, so that it shall be seen as distinctly as it was in daylight. Keep the right eye fixed on this object for about a minute, so as to examine it closely and narrowly, then extinguish the candle or lamp, open the shutters, and uncover the left eye. When both eyes are now turned to the ceiling, it will appear somewhat dim and indistinct; and on looking at it first with the one eye, and then with the other, the difference will be very remarkable. To the left eye, which had not been exposed to the action of the artificial light, it will appear unchanged, or sometimes of a pale yellowish-white color; but to the right eye it will be *very dim and of a dark*

blue or purple color. The effect produced upon the right eye in this experiment soon goes off; and though it always takes place to a certain extent when artificial light is used, it is not much observed, because as both eyes are equally affected, the contrast is not very striking. But if any one will read or write by candlelight for some hours with one eye closed, he will be rendered fully sensible of its very injurious action, when he afterwards compares the state of one eye with that of the other.

254. **Explanation of these effects.**—We shall understand these effects by recalling what has been said of complementary colors (173). When the nerve of vision is exposed to a colored light, it is unequally excited. The equilibrium of its action seems to be disturbed. It becomes less sensitive to the observed color, and when the eye is afterwards turned to white objects, they do not appear white but tinged with the complementary to the one seen first. The continued action of one color seems to paralyze the retina to its influence, and produce an unnatural sensibility to the other colors, which, combined with that, compose white light. In the preceding experiment, the eye, stimulated by candlelight, in which orange-yellow is in excess, temporarily lost its power of discerning white, and saw in it only the complementary of orange-yellow, blue or dark violet.

255. **How this may injure the Retina.**—Now the effect of this over-stimulating the nerves of vision through excess of red and yellow rays, on the part of those who use their eyes much by artificial light, is often to produce at certain points of the retina a total insensibility to those rays. The consequence of this is, that in daylight dark films of a blue or purple color, which are complementary to the orange or yellow color of the artificial light, appear before the eyes. The peculiar color of these films is not very obvious, unless they are seen in contrast with a yellow or orange surface, and over them they appear very sombre and almost black; because, in the peculiar state of the eye that gives rise to their appearance, there always coexists a certain degree of diminished sensibility to all the rays composing white light.

256. **Popular recognition of the effect of different Colors.**—There is a difference in the effect of different colors upon the eye, which is generally recognized and variously expressed. Thus blue is said to be a very soft, cool, *retiring* color; green is cool, though less so than blue; yellow is warmer and *advancing;* orange still warmer, and red, *fiery*, *harsh*, and *exciting*. This agrees with the view which regards blue and green as least hurtful, and yellow, orange and red as more

irritating and injurious to the eyes. An explanation of these different effects is found in the wave theory of light and colors, which has been previously noticed (155). Vibrations of the red ray are larger and more forcible than those of the yellow, and the yellow than those of the blue, just as the large and slow heavings of a swell upon the ocean are more violent and irresistible than the smaller and quicker ripple-waves.

257. **Heat accompanying Colors.**—The above current phrases in reference to the coolness and warmth of color, correspond perfectly with the distribution of measured heat among the several colors of the spectrum. We all know that heat is associated with light; but it is not equally associated with each color that composes the light. When the colors of the sunbeam are separated and spread out as in the spectrum, it is found that the heat is least intense at the blue, and constantly increases through the green, yellow, orange, and is most intense in the red color. Thus ENGLEFIELD found that while the blue rays were at a temperature of 56°, the yellow were at 62°, and the red at 72°. Thus the orange and red of common artificial light are actually more fiery and exciting than the absent blue rays. This accompanying heat is apt to be much more injurious in artificial than in natural light. The sun's rays are seldom, if ever, allowed to fall directly on a near object on which the eyes are to be employed for any length of time, without having previously undergone repeated reflections from the atmosphere and clouds, or from the surface of the ground and walls and furniture of the apartment, which absorb a great portion of their accompanying heat. But owing to the non-diffused and concentrated character of artificial light, the rays must be generally allowed to fall directly on the object looked at, from which they are reflected to the eye along with nearly the whole of their accompanying heat.

258. **The Luminous Matter being imperfect, more must be used.**—The luminous effect, or as it is termed the *defining power* of light, that quality by which we are enabled to see minute objects with the most distinctness and ease, is much less in artificial light than in the white light of day. This lower defining power of orange-colored light makes it necessary to increase the amount of the inferior rays; we attempt to compensate for deficient *quality* by excess in quantity. In reading by daylight the black ink is strongly contrasted with the pure white paper; but by artificial light, as the paper has an orange or yellow hue, the contrast is not so marked, and so to aid vision, the quantity of light is increased. In severe, long-continued, and nightly exercise,

as in reading, writing, sewing, type-setting, &c., the injurious consequences of impure light are apt to be heightened by its excessive use.

259. **Carbonic Acid affects the Eyes.**—Sunlight does not poison the air, artificial light does. In proportion to its brilliancy and abundance, the insidious narcotic agent, carbonic acid gas, is generated and set free. The effects of breathing this substance will be described when treating of the air and ventilation (293); but it may be remarked, that by its special influence in deranging and disordering the nerves, it is fitted to concur with those influences which impair the action of the retina.

260. **Unsteadiness of Artificial Light injurious.**—Sunlight never wavers or flickers; its action upon the eye is equable and unvarying. But in artificial illumination, as it is impossible perfectly to regulate the supply of air and of combustible material, the light is flickering and unsteady. The glass chimney of the Argand burner, however, produces the most constant and unchanging flame. The bad effects of these sudden and continual alterations in the brightness of artificial light, may be shown by supposing that a minute object can be seen in light of 8, 9 or 10 degrees of intensity, but that the intermediate degree of 9 is best .Now if sunlight be used, as it flows in a perfectly uniform manner without sudden variations, the retina and pupil adapt themselves to its quantity, and the eye may be long used without fatigue. But if artificial light of 9 degrees be used, it may at one moment rise to 10, and at the next fall to 8 degrees, from the flickering of the flame, so that the retina and pupil have not time to accommodate themselves to the change, and a degree of temporary blindness or impaired distinctness of vision, results, which is very straining and fatiguing to the eye. To remedy this, the light is increased in intensity. If it be raised, say to 14 degrees, then it may be reduced to 13 or rise to 15 degrees, without immediate inconvenience to the eye; there being abundance of light, its variations are less sensible. This relief, however, is fraught with ultimate danger; for the retina is too much excited by this increase of one-half in the quantity of light admitted to it; and this state of excitement is but the prelude to an opposite state, in which the sensibility to light is greatly, and perhaps permanently diminished (265). Unsteadiness of the object viewed, if the eye be long and closely directed to it, is a source of injury. It is thus that much reading in railroad cars, where the trembling or incessant movement of the print keeps the image in constant motion upon the retina, has a bad influence upon the eye.

261. **All Light injurious but that from the objects viewed.**—The distinct-

ness of vision is interfered with, and the eyes made to suffer by another important circumstance—the admission of light into the eye from other sources than objects to which sight is directed; in other words, the introduction of extraneous light into the eye. Impressions upon the retina may be diminished and obliterated by other rays falling upon it, which excite the nerve more strongly. The moon at night, as we all know, produces a vivid impression upon the nerve of visual sense. It produces precisely the same impression in the daytime, but *then* the luminous image is extinguished by the overpowering light of the sun, so that we are not conscious of it. When we are using the eyes upon any object, all light which enters them, *except from that object*, is injurious; that is, it has a blinding effect. This is shown by the greater clearness of objects seen through a tube, where all the diffused and side-light is excluded, on the same principle that persons see stars from the bottom of a well in the daytime.* Or it may be shown in another way. Let a person stand before a gas-light in such a position, that in reading a book a considerable number of the direct rays from the flame shall enter the eye. Let him then cautiously reduce the light by turning the stop-cock until the letters can be no longer distinguished. If he now shade his eye by interposing his hand or a screen, so as to cut off the direct rays, the words will again become visible, and again disappear when the hand or screen is removed. This proves that when the eye is protected from the direct rays, small objects can be seen with less light, and consequently with less injury to the nerve of vision.

262. **Prevalence of this source of injury.**—Upon this point Dr. HUNTER remarks: "Though the injurious action of artificial light, in consequence of its improper position, can be easily obviated; it is astonishing how little it is attended to, and how generally it is in operation. For the express purpose of satisfying myself on this point, I have visited a great many workshops, printing-houses, tailors' rooms, and other places, and in almost every instance I found the artificial lights placed close to, and directly opposite the eyes of those engaged in fine work, requiring the excessive exertion of the sight, and frequently the mischief was increased by concave metallic reflectors, placed behind instead of around the light. Now that gaslight is so generally employed, its improper position is a most serious evil; for as its intensity can be so easily increased in proportion as the sensibility of the eye becomes impaired, few persons, particularly those who are ignorant of the harm they are doing, can resist the temptation to use a

* HUMBOLDT, however, questions if stars are ever thus seen.

stronger and stronger light, till at last their sight is permanently weakened or even quite destroyed."

263. **Bad Light may inflame the Eyes.**—The continued action of improper light upon the eye is liable to inflame it. The first symptom is a reddening of the lining membrane of the eyelids, which in health is of a white or pale rose-color. This may be observed by gently drawing down the lower lid, when its surface will be seen injected with blood and of a deep red color. At first there may be but little uneasiness in the daytime, but at night, when the eyes are employed on objects illuminated by a candle, they become hot, watery, and irritable, the lids feeling dry, stiff, and itchy, and causing the patient constantly to rub them. The dryness, after a time, may give place to a copious flow of burning tears, which suffuse the eyes, and pour over and scald the cheek. Sometimes there is an excess of gummy and adhesive secretions, which dry at night and glue together the lids so hard as to require long bathing with warm water before they can be opened. If this incipient inflammation be unchecked, it may increase and run on to various forms of disorganization, or it may take the shape of a chronic or unmanageable affection of the eyes without producing blindness.

264. **Unnatural increase in the sensibility of the Retina.**—In the preceding case, the disease is located in the external or *image-forming* portions of the eye, but the bad management of artificial light is apt to engender a far more dangerous and intractable form of disease, which fixes itself upon the *image-feeling* parts—the retina and optic nerve. The excessive use of impure light, by its unequal action, excites and stimulates the nerves of vision, producing an unusual irritability to light, and a low degree of inflammation of the retina. Moderate light becomes unpleasant, and the individual, after looking steadily at some object for a few minutes and then closing the eyes, or putting out the light, appears to see still before him quite a distinct representation or image of the object, which may last for two or three minutes, and be variously colored or pass through a succession of colors. It moves, but its motions are in opposite directions to those of his eye, for it passes upwards when he looks downwards, and sinks downwards when he rolls his eyeballs upwards. It is caused by the morbidly increased sensibility of the retina, which retains the impressions of light for a greater length of time than when it is in a healthy condition. This state of the eye is accompanied often during the daytime by a dull, heavy feeling in the forehead, hardly amounting to pain, but causing the patient frequently to pass his hand across his brow, and in read-

ing or writing at night, there is an unpleasant sense of distension in the orbits, with an increased flow of tears and frequent twittering or quivering of the eyelids. Brilliant flashes of fire are seen, particularly when the eye is touched, on lying down, and after reading, writing, or sewing for some time by artificial light.

265. **Decrease in nervous sensibility—Appearance of dark films.**—This condition of excessive irritability may continue for months, and then be followed by others totally different, and indicating a diminished sensibility of the nerves of vision. This is evinced by the appearance of dark spots or films floating in the air. At first but one film appears before each eye, which is seen only for a moment, and then darts away, shortly to reappear. But afterward their number is increased, they appear oftener, are larger, darker, more opaque, and continue longer visible than at first. They sometimes look like cobwebs, or flakes of soot, or bunches of fur-down. They often resemble large-sized leaden shot, or minute and transparent globules, looking like drops of oil upon the surface of water, and, connected with each other like the links of a chain, float slowly through the air. These appearances are known by the doctors as *muscæ volitantes;* they are probably connected with morbid conditions of the nerves, but how we do not know.

266. **Paralysis of the nerve of vision—Amaurosis.**—These appearances, in their less marked form, are quite common, many eyes being subject to them, and they may occur for a long time without getting worse, and unaccompanied by positive disease. But when they appear as a dense, opaque, stationary film, which interrupts and obscures vision, the symptoms become very alarming; there is danger of palsy of the retina producing nervous blindness, or *amaurosis.* To the casual observer, the eye, under the influence of this malady, appears perfectly well, there being no external evidence of disease. But when once seated, its effects may be seen in the irregular shape of the pupil, which loses its roundness while the motions of the iris under the influence of varying light, become sluggish and imperfect, or are altogether lost. Objects appear clouded in a thick mist, and the air sometimes seems filled with sparkling, glittering points. In the final stages of amaurosis the pupil is very much dilated, the sight is impaired or quite gone, and the eye has a lustreless, dead appearance. As the disease advances pain ceases, the light, instead of being disagreeable, as at first, can hardly be procured of sufficient intensity. The patient resorts to spectacles of a high magnifying power, which condense a great quantity of light upon the palsied nerve of vision; these may afford transient aid, but do ultimate injury. This disease may require

from a few months to several years to run its course, but amaurotic blindness is regarded as incurable.

267. **Who are most subject to amaurotic disease.**—Amaurosis may arise from other causes than the improper use of artificial light, but Dr. ELLIOTT states that nearly two-thirds of all the cases of this disease which are met with in practice, occur in those who use their eyes much by artificial light, such as literary men, students, compositors, tailors, seamstresses, shoemakers, engravers, stokers, glass-blowers, &c. He also remarks that some individuals are more liable than others to suffer from the injurious action of artificial light, particularly those of a fair complexion and with gray or light blue eyes.

XI.—MANAGEMENT OF ARTIFICIAL LIGHT.

268. **Effect of ground glass Shades.**—We have stated (261) that all light which is more intense than that coming from the object viewed, dazzles the eye and weakens the impression of the object, causing it to appear less clear and distinct. To cut off these blinding rays from the flame itself, translucent screens of ground glass, called *shades*, globe-shaped, or of any other desirable figure, are made to surround the luminary, and have the effect of deadening the light in a surprising manner. The outline of the flame disappears, while the rays of light come from the surface of the globe, which thus appears self-luminous, and emits a diffused and softened light. As the rays cross each other at all points, and are scattered in all directions, objects near by throw only short, indistinct shadows, and there is a general and equal illumination. These shades should be used whenever it is desired to reveal to the best advantage the objects of a room, but where the vision is to be specially exerted upon particular things, their use is unfavorable, as by diffusion there is considerable loss of light. Objection has been made to the employment of ground glass and semi-transparent white ware shades, on the ground that by scattering the light they expand the impression over a larger surface of the retina; but as the image enlarges in area, it diminishes in intensity, which is desirable, unless the eye is constantly engaged in the scrutiny of minute objects.

269. **How to collect the Light—Reflectors.**—It is apparent that the radiation of light in all directions, is favorable to the equal illumination of objects distributed in all parts of the room. But when we desire to view closely minute objects, as in reading, writing, sewing, &c., it is necessary to concentrate upon the point of observation the light which would be otherwise wasted by general diffusion. To collect the rays,

and direct them to the part where they are required, conical shades or reflectors, of tin, paper, or some other opaque substance, and usually polished or whitened on the inside, are made to surround the flame. These not only protect the eyes from the glaring rays, but direct downwards that which would escape in other directions and be lost.

270. **Blue Shades to supply the missing rays.**—To remedy the defects which arise from the bad composition of artificial light, several expedients have been suggested. It is proposed to surround the flame with a conical shade, the inner side of which is sky-blue. As the light that passes upward, falls upon this surface, its red and yellow colors are absorbed, and the few blue rays which it contained, being thrown downward by the sloping sides of the reflector, mingle with the orange light, proceeding directly from the flame, and improve the bad color by imparting to it a higher degree of whiteness. As in this case a portion of the reddish yellow rays are absorbed, there is a loss of light. If a common white reflector is used, more luminous matter is thrown down than with the blue shade, and a stronger illumination is produced. But, with a blue reflector, although there is less brilliancy, the light is whiter, purer, and has a higher defining power, while it is cooler, more agreeable, and less injurious to the eyes.*

271. **Structure and mounting of these Shades.**—Shades of bristol-board, or strong paper, or silk, may be made by any one. The material is to be cut into the shape exhibited in Fig. 64, and then the edges, *a a* and *b b*, are to be united to each other, which gives rise to the conical structure shown in Fig. 65. This may be mounted upon a wire frame, which is to be hooked on to the glass chimney, or ground shade, or in the absence of these, a wire framework may be supported by the body of the lamp. If the reflector be made of metal, as tin or copper, it may be sustained either in the way described or by a three-branched support, screwed on to the burner. Reflectors are adapted to candles by attaching to the candlestick an upright brass rod, on which the reflector slides, being fixed at any point by a thumb-screw. This is shown in Fig. 66.

FIG. 64.

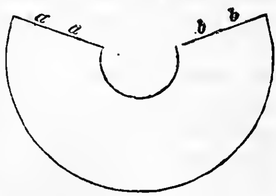
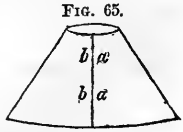


FIG. 65.

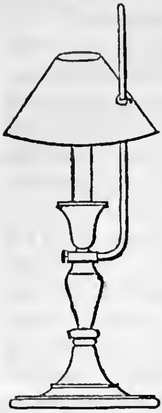


272. **How blue Reflectors should be colored.**—The most pure and unchangeable blue color is ultramarine, and this is best

* E. V. HAUGHWOUT, of 490 Broadway, N. Y., furnishes these shades.

adapted for painting the inner surface of shades. Prussian-blue decomposes and turns green by exposure to the heat, and other coloring matters are liable to fade or change. The colored surface should be smooth, but without gloss or varnish, the surface appearing dead, or, as it is technically termed, 'flat.'

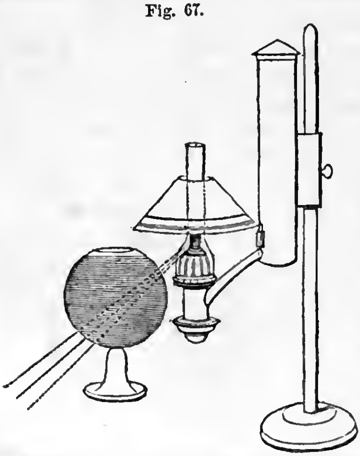
Fig. 66.



Candlestick with shade.

273. **Artificial Light whitened by absorption.**—Blue, transparent media absorb the yellow and red rays, and transmit only those of blue. If the glass chimney of a lamp be tinted lightly and evenly with a mixture of ultramarine and mastic varnish, the offensive orange will be separated from the light as it passes through, but at the expense of its brilliancy; there will be much less of luminous matter. But if a polished tin or silvered reflector be employed to collect the rays, it will throw downward a beautiful soft white light. If the light from a luminary which is surmounted by a white or polished reflector (Fig. 67) be made to pass through a glass globe filled with water which has been slightly blued, its color will be improved, while to compensate for the loss of luminous matter absorbed, the spherical form of the water-bottle will serve to converge or gather the rays so as greatly to increase their illuminating power, at the point upon which they fall. Melloni has proved that when the rays of artificial light are passed through even a very thin stratum of water, their heating power is diminished by eighty-nine per cent., but with little increase in the temperature of the water, in consequence of its great capacity for heat (49). The water-globe thus transmits a *cooler* as well as a whiter and purer light. Lamp-globes made of glass, slightly blued in its composition, would be very desirable.

Fig. 67.



Whitening the rays and straining them of their heat.

274. **Colored glasses for Spectacles.**—The indiscriminate use of these

is altogether objectionable. They place the eyes in very unnatural conditions as regards the light, and if their employment is persisted in, it impairs their sensibility to the true relations of color, and otherwise injures them, as we have just seen that artificial colored light is able to do (253). If we look through a glass of any color, the effect is, that when it is withdrawn, the eye sees all objects tinged by its complementary. As the colored glass cuts off a large quantity of light, its removal produces a sudden and injurious impression. Faint blue glasses may be serviceable in using artificial light. Colored glasses absorb and accumulate the heat so as in many cases to be disagreeable. Their bad effects are more marked, as it is for 'weak' eyes that they are generally commended. They may, at times, be of service to protect the eye from an intense glare, as of snow or the surface of water in sunshine. Gray glasses, or what is called a 'neutral tint,' that is no particular color, are perhaps best; they should not be of too dark a shade.

275. **Is Gas-light injurious?**—There is a prejudice against gas-light, as being the most injurious form of artificial illumination. As against the proper and well-regulated use of gas, this prejudice is entirely groundless, but there can be little doubt that from its abuse and bad management it is really doing more mischief than any other kind of light; its very excellencies are turned to bad account; its extreme cheapness, compared with other sources of illumination, naturally leads to its use in excessive quantities; floods of light are poured forth, so that persons may read and sew for hours together in the remotest corners of the room. The air is heated by the excessive combustion, and poisoned by large quantities of carbonic acid, which there are no means of removing. The eye is unprotected from the glare by screen or shade; extraneous light is freely admitted, which obscures the impression and strains the nerve of vision, and in proportion as the sensibility of the eye is impaired, stronger light is used, which gives temporary relief, but with danger of ultimate and permanent injury to the sight. On the other hand, good, well purified gas, judiciously controlled in accordance with the hints we have given, and others to be offered in the next part, is perfectly harmless (360).

PART THIRD.

AIR.

I.—PROPERTIES AND COMPOSITION OF THE ATMOSPHERE.

276. **Part it plays in the scheme of Nature.**—It is impossible to contemplate the wonderful properties of the atmosphere without a feeling of profound amazement. Whether we regard it as the grand medium of water circulation, through which rivers of vapor lifted from the oceans are carried landward, to be condensed and channel their way back again to the sea; or as the scene of tumultuous storms, generating the lightnings within its bosom, and taking voice in the reverberating thunders; whether as hanging the landscape with gorgeous cloud-pictures, or as the vehicle through which all melody and beauty and fragrance are conveyed to the portals of sense—it is alike strange and interesting. But when we glance at its deeper mysteries, those intimate relations to life which have been disclosed to modern science; when we consider that the vegetable kingdom not only has the same chemical composition as the air, but in its mass is actually derived from it; that the whole architecture and physiology of trees, shrubs, and plants, are conformed to atmospheric nutrition, so that in literal truth the forests are but embodied and solidified air, the subject rises to a still higher interest. And more startling yet is the surprise when we recollect not only that the materials of our own bodily structures, derived from vegetation, have the same atmospheric origin; but that active life, the vital union of body and spirit, and all the powers and susceptibilities of our earthly being are only maintained by the action of air in our systems;—air which we inhale incessantly, day and night, from birth to death. There is an awful life-import in these never-ceasing rhythmic movements of inspiration and expiration, this tidal flux and reflux of the gaseous ocean through animal mechanisms. Shall we question that it is for an exalted purpose? Science has many

things to say of the relations of air to life, but it can add nothing to the simple grandeur of the primeval statement, that the Creator "breathed into his nostrils the breath of life, and man became a living soul."

277. **Air a material reality—Its pressure.**—The atmosphere is so thin and invisible, and so totally unlike the objects that present themselves to our most impressible senses, that we are half inclined to forget that it is a reality, and are too apt to think of it as being mere empty space. Yet it consists of ponderable matter, and is heavy, just like the solid resisting objects which we see and handle, and it presses down upon the ground with a force proportional to its weight. Upon every square inch of the earth's surface there rests about 15 lbs. of air. Upon the body of a medium-sized man, having a surface of 2,000 square inches, the atmosphere exerts an external crushing force of 30,000 lbs. But there is air also within the system which exerts an equal outward pressure, and thus prevents injury. The pressure of air upon the body is not the same at all times. There are tides in it, just as there are in the ocean, great atmospheric waves which regularly sweep over the earth and cause the weight of the atmosphere to vary. Winds and storms produce similar effects. These variations in atmospheric pressure are measured by the barometer (60), and they are so considerable that a man's body may sometimes have from one to two thousand pounds more pressure upon it than at others. Of course, as the pressure upon the air increases from above, more of it is crowded into the same space, and it becomes more *dense*. The maximum height of the barometric column, therefore, corresponds to the greatest density of the air, and a low condition of the mercury to *rarity* of the air.

278. **Weight of various masses of Air.**—As the air is thus ponderable, it is desirable to obtain definite ideas of the proportion between its bulk and weight. A cubic foot of air weighs 538·1 grains, or something more than an ounce. 13·06 cubic feet weigh 1 lb. About 65 cubic feet of air furnish 1 lb. of oxygen. An apartment 8 feet high, 12 wide, and 13 long, contains about 100 lbs. of air; and a room 40 feet square and 18 feet high contains about a ton. The atmosphere is estimated to be 45 or 50 miles high, but the great mass of it lies close to the earth, as it grows very rapidly thinner and rarer in ascending from the earth's surface. Indeed if it were all the way up of the same density as that which we breathe, it would be only about five miles deep, just sufficient to cover the highest mountains.

279. **Effects of varying pressure of the Air.**—Every variation of at-

mospheric pressure must decidedly influence the state of the body, modifying, as it were, the *tension* of the whole fabric, affecting the pores of the skin, the cells of the lungs, and the circulations within the system. The constitutions of many invalids, especially the asthmatic and consumptive, are undoubtedly much influenced by changes of atmospheric density. As the barometer falls and the air becomes lighter, the tendency to evaporation from all surfaces, and the amount of expansion in all the more compressible tissues increases. As the lungs have a constant capacity, and consequently receive the same bulk of air at all times, it is clear that the quantity taken into these organs to act upon the blood will vary with its density, there being of course more matter in a chest-full of dense air than in a chest-full of light air. Such changes, which powerfully influence the general rate of action within the system, must affect the mind as well as the body, and assist to explain the fact that "persons are often joyful, sullen, sprightly, hopeful and despairing, according to the weather, while there are days in which the faculties of memory, imagination and judgment, are more acute and vigorous than others." Every alteration of an inch in the mercury of the barometer adds or removes a weight of 1,080 lbs. from the average weight which a man of common stature sustains. The effects of sudden alterations of this pressure, as when the barometer is subject to rapid and extreme variations, often appear in the shape of headache and apoplexy (779). Yet in this, as in numerous other cases, it is remarkable to what different states the system can habituate itself. SAUSSURE, at the summit of Mont Blanc, had scarcely sufficient strength to consult his instruments; while at heights scarcely inferior, South American girls will dance all night. The influence of fluctuating pressure of the air is of great importance to the inhabitants of low, swampy, malarious districts of country. The amount of exhalation and effluvia which rise from the ground depends much upon atmospheric pressure. When the air is heavy, these substances are, as it were, confined to their sources, that is, they are liberated at the slowest rate; but as the barometer falls the pressure is taken off, and the miasmatic emanations rise much more freely (301).

280. **Of what the Air is composed.**—Now we can study all about atmospheric pressure, and many other things concerning the air, without ever asking what it is made of; but before we can know why it is that animals breathe, we must understand its chemical properties. We have referred to the constituents of air in connection with the subject of combustion (74); we are now to examine its composition

and endowments more fully in relation to life. The atmosphere consists of four substances,—a pair of *elements*, nitrogen and oxygen, and a pair of *compounds*, carbonic acid gas and vapor of water. Dry air contains by weight very nearly 77 per cent. of nitrogen to 23 of oxygen. The proportion of moisture in the atmosphere varies with the temperature; when saturated at 60°, it contains about 1 per cent., and it has an average of about 1-2000th of carbonic acid. These proportions are thrown into visible form by the diagram (Fig. 68). In addition to these definite and stable elements, of which the atmosphere is universally composed, various gaseous exhalations from the earth

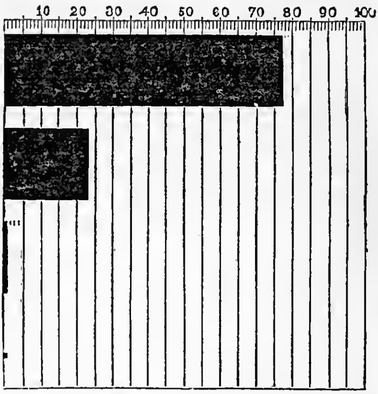
FIG. 68.

Nitrogen, or the *diluting* constituent of the Air.

Oxygen, or the *active* constituent of the Air.

Moisture, or the *variable* constituent of the Air.

Carbonic Acid, or the *poisonous* constituent of the Air.



The areas of blackened surface represent the relative proportions by weight of the constituents of the Air.

constantly enter it, though so minutely as generally to elude detection and identification. LIEBIG has shown that a trace of ammonia is always present in it (299).

281. **Intermixture, or diffusion of Gases.**—These gases have different weights. The oxygen is slightly heavier than the nitrogen; the watery vapor is much lighter than either, and the carbonic acid about half as heavy again as the air itself. It might seem, then, that if they were mingled together they would gradually separate and arrange themselves in distinct layers, the heaviest at the bottom and the lighter above. Some works on ventilation have actually stated such to be the case, and that when we breathe out vapor of water and carbonic acid, the former rises while the latter descends. One of them remarks: "were these different portions of air as they come from the

lungs, of different colors, we should, in a perfectly still atmosphere, see the stream divided, part of it falling and part ascending." This, of course, is not true. If such were the fact, if gases tended to arrange themselves in the order of their gravities, and there were no universal and inflexible law to prevent it, the carbonic acid of the air might slowly sink to the earth, and form a deadly stratum 10 or 15 feet deep over its entire surface, or fill up all its valleys with treacherous invisible lakes of aerial poison. But such is not the tendency of things. Gases brought together, no matter what their different weights or varying proportions, diffuse throughout each other so as to become perfectly and equally commingled. Heavy gases will rise up to mix with lighter ones, and lighter gases descend to mingle with those that are heavier. As a consequence of this important law, the proportions of the atmospheric gases to each other are kept extremely uniform, being scarcely, if at all, influenced by season, climate, wind, weather, or even the salubrity of the air. How benign and admirable is this provision of nature, by which, without being aware of it, we are relieved at every instant of a deadly though invisible poison, the process continuing as well during sleep as while awake, and taking place as perfectly for the unconscious babe as for the matured man. This great law secures the unity of the atmosphere. Its ingredients are perfectly mingled and equally diffused throughout each other, but not *chemically combined*, so that in breathing, although we separate the constituents of the air, we do not have to chemically decompose it. When we speak of air we mean the mass of commingled gases acting together; yet as each constituent preserves its identity, and produces its peculiar effects, it is necessary to consider them separately.

II.—EFFECTS OF THE CONSTITUENTS OF AIR.

1. Nitrogen.

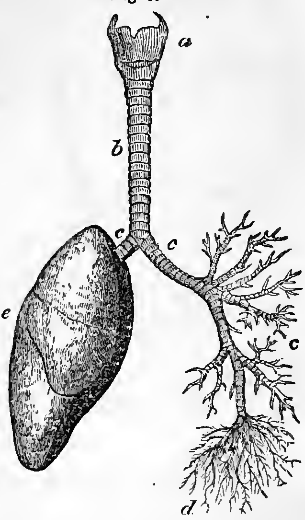
282. This gas seems to take no active part in breathing; it passes out of the body as it entered it, without being changed. A fire cannot be kindled in it, and an animal breathing it quickly dies, though not from any positive noxious effect which it produces, but rather from *want* of something else. Nitrogen is a negative or inert substance, its chief use being to dilute or temper the other active ingredients of the air to a proper degree of strength.

2. Oxygen.

283. **How the System is charged with Oxygen.**—Of the wonderful in-

fluence of this agent we can here speak but briefly, as the subject will have to be considered again more fully in treating of the action of foods. We have noticed that oxygen is the active agent in combustion, so it is also in breathing. It is on account of what it does in our system that we respire the atmosphere. The air enters the lungs through the windpipe and bronchial tubes or air-passages, as seen in Fig. 69. It fills and distends the numberless little cavities or air-cells, which are enclosed by these membranes, and overspread with the finest network of capillary blood-vessels. Oxygen then penetrates or passes through the delicate membrane and enters the blood, imparting to it a bright crimson color, and rushing forward with it through what is called the pulmonary vein (Fig. 70) to the heart. It is estimated that the lungs contain, on an average, 220 cubic inches of air, with an inner membrane surface of 440 square feet, nearly thirty times greater than the whole exterior of the body.* This vast extension of surface is to secure the largest and most perfect opportunity of action and reaction between the air and blood. From the heart the blood passes by the arteries to all portions of the body. These arteries divide and subdivide until they are reduced in size to the finest hairlike tubes, which are densely interlaced throughout all the tissues of the body. The arterial channels thus represent streams of oxygen flowing from the lung fountains to every portion of the system. In this way each minute part of the living fabric is in direct communication with the external air, that it may receive from it the agent upon which it immediately depends for the performance of its vital offices. This system of arterial currents, bearing oxygen *from* the air to every portion of the system, implies a set of counter-currents to drain off the poisons generated within the body, back into the air. This is the duty of the veins or venous system. In the accompanying diagram (Fig. 70), the fine

Fig. 69.

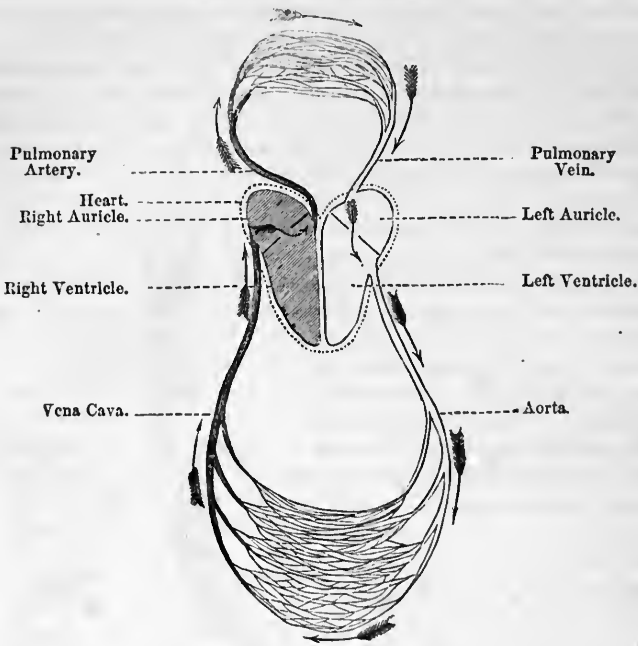


Human Lung.
a the larynx; *b* windpipe; *c c c* bronchial tubes or air passages; *e* lung.

* Dr. ADDISON estimates the number of air-cells in the two lungs at 1,744,000,000, and the extent of the membrane at 1,500 square feet.

vessels at the top represent the lungs, and those at the bottom the capillaries of the whole body. The double circulation is shown, and how the heart is related to it. The vessels on the right side represent the arteries carrying blood charged with oxygen, and those on the left side, the veins, conveying carbonic acid.

Fig. 70.
Lesser or Pulmonary Circulation.



Greater or Systemic Circulation.

284. **What Oxygen does in the body.**—The purpose of this incessant inflowing stream of oxygen, is to carry forward the great operations of the vital economy. Oxygen has a wide range of chemical attractions, and combines with other elements with intense energy. It is the ever-laboring, tireless Hercules of the atmosphere. As it kindles and maintains the combustion of our fires, so it does our bodily vitality. The muscles are called into action through decomposition by oxygen, and as with the muscles in the manifestation of mechanical force, so with the brain in the exercise of intellectual power. This

organ is on an average only about $\frac{1}{36}$ the weight of the whole body, yet it receives from $\frac{1}{5}$th to $\frac{1}{10}$th of the entire oxygenated stream from the lungs and heart. A torrent of oxygen is thus poured incessantly into the material apparatus of thought to carry forward certain physiological changes upon which thinking depends. If the arterial stream be cut off from a muscle, it is paralyzed; if it be stopped from the brain, unconsciousness occurs instantaneously. In proportion to the activity of muscle is its demand for the destructive agent; in proportion also to the activity of the mind is the brainward flow of arterial blood.

285. **Effects of varying the quantity of respired Oxygen.**—If an animal be deprived of this gas, it dies at once. If man undertake to breathe a less proportion than that naturally contained in the air, the effect is depression of all the powers of the constitution, physical and mental, to an extent corresponding with the deficiency. If the natural amount be increased, there is augmented activity of all the bodily functions, the life-forces are exalted, and the vital operations are driven at a preternatural speed. If pure oxygen is respired, the over action and fever become so great that life ceases in a short time. Nitrous oxide (*laughing gas*) is a compound rich in oxygen, and when presented to the blood it absorbs a much larger proportion of it than of pure oxygen. Hence, when this gas is breathed, the blood drinks it up rapidly, and the system becomes so saturated with it as to produce the most remarkable effects. The muscular energy is so aroused that the inhaler is often impelled to extraordinary feats of exertion, and the intellectual powers are excited to a delirious activity.

3. Moisture.

286. **How much moisture the Air contains.**—The third constant ingredient of the air is moisture, derived from evaporation upon the earth's surface. The quantity which the air will hold depends upon its temperature, and hence fluctuates greatly. At zero a cubic foot of air will hold but ·18 of a grain of watery vapor; at 32° it will contain 2·35 grs.; at 40°, 3·06; at 50°, 4·24; at 60°, 5·82; at 70°, 7·94; at 80°, 10·73; at 90°, 14·38; at 100°, 19·12 grains, and as the temperature goes higher still, the *capacity* for moisture also increases (308). After the air has imbibed its due quantity of vapor, at a given temperature, it is then said to be *saturated*, and will receive no more unless the heat be increased. To better appreciate how rapidly the capacity for moisture augments, as the temperature ascends, we will state the proportions in another form. A quantity of air absolutely saturated at 32°,

holds in solution an amount of vapor equal to the $\frac{1}{160}$ part of its weight; at 59°, $\frac{1}{80}$; at 86°, $\frac{1}{40}$; at 113°, $\frac{1}{20}$; and at 140°, $\frac{1}{10}$.

287. **Conditions of the drying power of the Air.**—If, when the air is saturated, its temperature falls, a portion of its moisture is *precipitated*, that is, it does not remain dissolved, but appears in drops of dew. Thus a cubic foot of air, saturated at 90°, if cooled 10° would deposit 3·5 grains of water. Until it is saturated, air is constantly absorbing moisture from all sources whence it can procure it. A cubic foot of air at 90°, and containing but 8 grains of moisture, is capable of absorbing 6·3 more, and this is the measure of its *drying power*. Watery vapor is lighter than the air, and when mingled with it increases its levity in a degree proportional to its temperature. This is one of the causes of the ascent of breath expired by the lungs, at the temperature of the body. In drying-rooms and laundries, if the openings for the escape of hot air be at the bottom, as the air gets saturated with vapor it becomes lighter, and rising, fills the room and stops the evaporation. If the opening be at top the loaded air rises and escapes, and the drying will be observed to commence at the bottom.

288. **Moisture in the Air of Rooms—Dew-point.**—It has been explained that the temperature at which air is saturated, and begins to condense its moisture in drops, is called the *dew-point* (34). When air contains so much moisture that its temperature needs to decline but little before water appears, the dew-point is said to be *high;* when it must lose much heat before drops are produced, its dew-point is *low*. Air, with a high dew-point, is therefore moist, while that with a low dew-point is always thirsty and drying. A simple means of finding out the dew-point, and ascertaining the drying power of the air, is as follows:—Note the temperature of the air by a thermometer, taking care that the instrument is not influenced by the radiation of any heated body in its vicinity. Then introduce it into a glass of water and gradually add a little ice, carefully watching for the first appearance of moisture on the outside of the tumbler. The temperature at which the deposit commences is the dew-point; and the difference between it and the temperature of the air, expresses its drying power. If the air is at 60° and moisture begins to be condensed at 40° its drying power is 20 degrees. MASON's hygrometer is a little instrument which indicates the dew-point without trouble. It has two thermometers, one of which gives the temperature of the air, and the bulb of the other, connected constantly with a reservoir of evaporating liquid, is kept cooled, and gives the dew-point; so that the amount of humidity in the air is seen at a glance

by comparing the two scales;—cost, from 3 to 5 dollars. From observations made at Washington through June, July, August, and September, from 9 to 3 o'clock of the day, the dew-point was, on an average, 11° below the temperature of the air, and sometimes more than 20° below. The air is always dampest near the ground; a difference in height of 60 feet, in the same exposure, has been known to make a difference of $10\frac{1}{2}$ degrees in the dew-point. In our houses, we are to imitate as far as possible the external conditions of the air. As the temperature of freshly drawn well water is about 50°, a vessel containing it should receive a deposit of moisture when brought into our rooms, if they have a temperature above 65°. It is very rare that any such deposit is seen in apartments heated by a hot-air furnace, even if a considerable quantity of water is evaporated.

289. **How double Windows affect the moisture of Rooms.**—Glass skylights often drip moisture upon those below, and we see it copiously condensed in winter upon the windows and trickling down the panes. This is often mistaken for a symptom of abundant humidity in the air, but it may occur when the air is extremely dry. When, as often occurs, air within a room is at 70° or 80°, while just outside the window-glass it is down to freezing, or below; the inner layer of air next the glass will rapidly deposit its water, and then falling to the floor will be succeeded by other air (337), so that the window acts as a perpetual drain upon the moisture of the apartment. It is often impossible to maintain the air properly humid on this account. People are misled by this copious deposit of dew upon the glass, and it is hard to convince them that the air is deficient in moisture when they can *see* it condensed upon the windows. We have referred to double windows as a means of saving heat, and we might have added that they are equally serviceable in summer to exclude its excess of heat; the enclosed air acting just as well to bar *out* the heat of the warm season, as to confine it within, in cold weather.* But double windows also prevent the deposit and loss of moisture from the air in rooms, and in this respect they are most useful. Glass is not essential to their construction, where we require only a diffused light; white cotton cloth stretched upon a suitable frame and rendered impervious to air by linseed oil or other preparation, will answer equally as well for preserving heat, and be much less expensive.

290. **Rate of Evaporation.**—When dry air is exposed to a source of moisture, a considerable *time* must elapse before it will become satu-

* If double windows are to be retained in summer, they cannot be used for airways, as single windows are made to do; there must be independent means of ventilation.

rated. The diffusion of vapor into hot air is much more rapid than into that which is colder, but it is not at all instantaneous. Mr. DANIELL observed, that a few cubic inches of dry air, continued to expand by the absorption of humidity for an hour or two, when exposed to water at the temperature of the surrounding air. In cold regions there is much less moisture in the air than in hot, and less in winter than in summer. It is also subject to a regular diurnal variation. As the sun warms the air during the day, evaporation is increased, and the humid element rises into the atmosphere; but as it declines toward evening, cooling begins, and at night the watery vapor again falls, and is deposited upon the earth. We are not to infer that because there is an absence of rain, therefore the air is dry; on the contrary, in long droughts the air is often heavily charged with moisture.

291. **How moist Air affects the System.**—The skin relieves the System of moisture in two ways; by insensible perspiration, and by sweating. Under common circumstances, the loss is six times greater by the former than by the latter process. The skin, as well as the lungs, is an excreting organ; it contains, packed away, some 28 miles of microscopic tubing, arranged to drain the system of its noxious matters, carbonic acid, &c., which, if retained in the body, become quickly injurious. The perspiration given off in this climate amounts to 20 oz. per day, and in hot countries to twice that quantity. But air which is already saturated with moisture refuses to receive the perspiration which is offered to it from the skin and lungs; the sewerage of the system is dammed up. Much of the oppression and languor that even the robust sometimes feel in close and sultry days, is due to the obstruction of the insensible perspiration by an atmosphere surcharged with humidity. Not only are waste matters generated in the system thus unduly retained, but malarious poisons introduced through the lungs by respiration, are prevented from escaping; which would lead us to anticipate a greater prevalence of epidemic diseases in damp than in dry districts. Such is the fact, as we notice in Cholera, which follows the banks of rivers, and revels in damp, low situations. Moisture joined with warmth is most baneful to the system. The American Medical Association report that during the remarkable prevalence of Sun-stroke in the city of New York in the summer of 1853, which almost amounted to an epidemic, the heat of the atmosphere was accompanied by great humidity, the dew-point reaching the extraordinary height of 84°. In Buffalo, in the summer of 1854, the progress of cholera to its height was accompanied by a steady increase in at-

mospheric humidity. Air which is warm and moist, has a relaxing and weakening influence upon the body. The *siroco* is invariably charged with moisture, and its effects upon the animal economy illustrate but in an exaggerated degree the influence of damp warm weather. When it blows with any strength, the dew-point is seldom more than four or five degrees below the temperature of the air. The higher its temperature, the more distressing its effects, owing to the little evaporation it produces. This, connected with its humidity, is the principal cause of all its peculiarities—of the oppressive heat—of the perspiration with which the body is bathed—of its relaxing and debilitating effects on the system, and its lowering and dispiriting effects upon the mind. —WYMAN. Damp air at the same temperature as dry air has a more powerful cooling effect, producing a peculiar penetrating chilling feeling, with paleness and shivering, painfully known to New England invalids as accompanying the east winds of spring.

292. **Effects of dry Air.**—Dry air favors evaporation. By promoting rapid transpiration from the pores of the skin, it braces the bodily energies and induces exhilaration of the spirits. Cold dry air is invigorating and reddens the skin, with none of the distressing symptoms of cold moist air. If very dry, it not only accelerates perspiration, but desiccates and parches the surface, and deprives the lining membrane of the throat and mouth of its moisture so rapidly as to produce an uncomfortable dryness, or even inflammation. Dry climates which quicken evaporation, are best adapted for relaxed and languid constitutions with profuse secretion, as those afflicted with humid asthma, and chronic catarrh with copious expectoration. The *Harmattan*, a dry wind from the scorching sands of Africa, withers, shrivels, and warps every thing in its course. The eyes, lips, and palate become dry and painful. Yet it seems to neutralize certain conditions of disease. "Its first breath cures intermittent fevers. Epidemic fevers disappear at its coming, and small-pox infection becomes incommunicable."

4. CARBONIC ACID.

293. **Physiological effects of Carbonic Acid.**—The fourth constant ingredient of the atmosphere is carbonic acid; a transparent, tasteless, inodorous gas. It takes no useful part in respiration, indeed it exists in the air in so small a proportion that its effects upon the system are inappreciable. Its sources are the combustion of burning bodies, fermentation and decay, the respiration of animals; and it is also generated within the earth, and poured into the air in vast quantities from

volcanoes, springs, &c. It may be set free more rapidly than it wil dissolve away into air; it then accumulates, as sometimes in wells, cellars, rooms, &c. and becomes dangerous. When breathed pure, it causes suffocation by spasmodically closing up the glottis of the throat. When mixed with air in small quantities, it is admitted to the lungs, and then acts as a rapid narcotic poison. The symptoms of poisoning by carbonic acid gas are throbbing headache, with a feeling of fulness and tightness across the temples, giddiness, palpitation of the heart, the ideas get confused and the memory fails. A buzzing noise in the ears is next experienced, vision is impaired, and there is strong tendency to sleep. The pulse falls, respiration is slow and labored, the skin cold and livid, and convulsions and delirium are followed by death. This gas has been often employed as a means of suicide. A Son of the eminent French chemist, BERTHOLET, under the influence of mental depression, retired to a small room, locked the door, closed up every crevice which might admit fresh air, carried writing materials to a table on which he placed a seconds watch, and then seated himself before it, described his sensations, and was found dead upon the floor.*

294. **Effects in small quantities.**—The proportion of carbonic acid necessary to produce a poisonous atmosphere is very small; so much so that in attempts at suicide by burning charcoal in an open room, the people who entered it have found the air quite respirable, although the persons sought were in a state of deep insensibility (*coma*). From 5 to 8 per cent. of carbonic acid in the air renders it dangerous to breathe, 10 to 12 makes it speedily destructive to life. The natural quantity in the air is so small that it may be multiplied 20 times before it rises to 1 per cent. Air containing one per cent. of this gas is soporific, depressing, takes from the mind its cutting edge, tends to produce headache, and is most injurious. That proportion of carbonic acid which nature has placed in the atmosphere, we assume to be

* "I light my furnace, and place my candle and lamp on the table with my watch. It is now 15 minutes past ten. The charcoal lights with difficulty. I have placed a funnel on each furnace to aid the action of the fire. 20 minutes past ten. The funnels fall: I replace them; this does not go to my satisfaction. The pulse is calm, and beats as usual. 10 h. 30. A thick vapor spreads itself by degrees in the chamber. My candle seems ready to go out. My lamp does better. A violent headache commences. My eyes are filled with tears; I have a general uneasiness. 10 h. 40. My candle is extinguished, the lamp still burns. The temples beat as if the veins would burst. I am sleepy. I suffer horribly at the stomach; the pulse beats 40 per min. 10. 50. I am suffocated. Strange ideas present themselves to my mind. I can hardly breathe. I shall not live long. I have symptoms of madness. 10 h. 60. [Here, he confounds the hours with the minutes.] I can hardly write; my vision is disturbed; my lamp flickers; I did not believe we suffered so much in dying. 10 h. 62 m. [Here were some illegible characters]."

entirely inoffensive, but the more it is increased beyond that amount, the less it is fitted for respiration. Precisely so with the body. Carbonic acid is continually generated within it and continually poured out from the lungs into the air; a certain amount in the blood is compatible with health, but if that quantity be slightly increased, it at once begins to act as a poison. Any cause, therefore, which hinders the escape of this gas from the lungs, tends to accumulate it in the blood and produce injury, and this is exactly the effect, if there be considerable carbonic acid in the air we breathe. Its exhalation from the lungs is retarded if the outer air already contains more than its usual amount of carbonic acid.

295. **Why then does the Air contain Carbonic Acid?**—But if this gas be useless, or positively detrimental in animal respiration, why is it made a constant and essential ingredient of the atmosphere? The plan of nature requires it. As it is formed in all animal bodies, and breathed out into the air, and also by all combustions, its presence there is unavoidable, while it is the great source of nourishment to the whole vegetable world, which drinks it in through innumerable pores in every green leaf, and thus keeps the proportion down to the point of safety for animals.

296. **Effect of these Ingredients combined.**—Such are the constant constituents of the air, and such, so far as it has been possible to determine it, is their separate influence upon man. The effects of the atmosphere we breathe are the resultant of these agents acting together. We see that it exerts an all-controlling influence upon the human constitution. To say that it is useful or important, gives us no adequate conception of the facts; it is the first condition of vital activity—what the stream is to the water-wheel or fire to the steam-engine—the immediate impelling power of life. Any one of its elements breathed alone would be fatal; any other proportions than those in which they are commingled would be dangerous or deadly. Its elements taken alone are poisonous and excoriating, but properly mingled and neutralized, how bland, how balmy, how innocent they become. Pressing upon us with the weight of tons, bathing the sensitive breathing passages—distending the filmy membranes of the air cells, flashing through into the blood and swept forward to the inmost depths of the system, corroding and consuming in its progress the living parts—and yet with such marvellous delicacy are all these things accomplished, that we remain profoundly unconscious of them. Unspeakable indeed are these harmonies of life and being, and how adorable the Power, Wisdom and Love from which they emanate.

5. Ozone and Electricity.

297. **Ozone in the Air.**—Our view of the properties of the atmosphere would be incomplete without reference to these agencies. Attention has latterly been drawn to the interesting and significant fact that the chemical elements are capable of existing in different states, with widely different properties and powers. We see this in the case of carbon, which assumes several states, as charcoal, lampblack, diamond. Sulphur, phosphorus, and indeed many of the other elements are found capable of this change of state, which is known as *allotropism.* It has been discovered also that the remarkable element *oxygen* has its double condition, its ordinary state and another of extreme activity, in which it seems to acquire new energies; in this heightened form of action it is called *ozone.* It may be readily changed from the common to the superactive state, acquiring bleaching and oxidizing energies which it had not before. Ozone is extensively formed in the atmosphere, by the operations of nature, although under precisely what circumstances we do not know. It is found more abundantly in some localities than in others, and may be generally recognized in air which has swept over the ocean, although usually absent in that which has traversed large tracts of land. There has been much speculation as to how the air is affected by its presence, in relation to health and disease. It is said that when present in excess diseases of the lungs, especially influenza, prevail; when deficient, fevers and all those diseases which are supposed to depend upon a kind of fermentation in the blood are common,—it being thought that ozone oxidizes or burns away the exciting fermentable matter, thus acting as a purifying agent. It has been stated that in cholera ozone is entirely absent from the air.

298. **Atmospheric Electricity.**—"I cannot tell," says Dr. Faraday, "whether there are two fluids of electricity, or any fluid at all;" such is our profound uncertainty in relation to this mysterious agent. Yet it is commonly assumed to be a subtle fluid, distributed through all substances, and lying buried beneath their surfaces in a condition of equilibrium, or rest. Various causes may disturb this state, producing *electrical excitement*, when the fluid is supposed to accumulate in some substances to excess, which are then said to be *positively* electrified,—while in others it is deficient, and these are *negatively* electrified. Some substances, as the metals, allow electricity to pass through them freely; these are called *good conductors;* others refuse it a ready passage, and are termed *non-conductors*, as silk, glass, air. When from any cause excitement has taken place, and a body has been charged with electri-

city, or robbed of it to a certain degree, there is an escape; if a good conductor be presented to it, it flows off quietly; if a bad conductor, it dashes through it, producing fire, light sound, and perhaps violent rupture (*disruptive discharge*). The friction of unlike bodies against each other creates electrical excitement. If we slide rapidly over a carpet, the body becomes so excited that it may yield a spark which will light the gas. The friction of masses of air, of different temperatures, or containing different degrees of moisture, by rubbing against each other, or grinding against the earth, developes electricity. So, also, does evaporation. If a saucer of water be suspended by non-conducting silk cords (*insulated*), evaporation goes on as usual at first, but is soon checked. It gives off positively electric vapor, while the saucer remains negatively electrified. If it be connected with the ground by a conductor, active evaporation is resumed. Combustion produces electricity; the escaping carbonic acid being positive, while the burning body is negative; the vapor of the expired breath is also positive. The air is generally electrified positively, especially in clear weather; but during the fall of rain, fogs, snow, and storms, it may be negative. The electricity of the atmosphere appears to have a daily ebb and flow, like the tides of the sea, twice in every 24 hours. It is feeble at sunrise, increases in intensity during the forenoon, declines again in the afternoon, until about two hours before sunset; it then advances until perhaps two hours after sunset, and again diminishes until morning. It has become fashionable, latterly, to offer electricity in explanation of all obscurities, material and spiritual. Beyond doubt it is profoundly involved in the phenomena of our being, but we as yet understand but little about it. In connection with the air, we can only say, that when it is clear, and electricity is rapidly developed, the spirits are more buoyant, and the feelings more agreeable, than when the atmosphere is in the opposite state.

III.—CONDITION OF AIR PROVIDED BY NATURE.

299. **Impurities of the external Air.**—There are natural causes which tend to make the atmosphere impure, but they act with variable intensity in different localities. Animal respiration and combustion exert a contaminating influence upon the atmosphere, but considering its vast mass, the general effect is but trifling, and besides is perfectly neutralized by growing vegetation, which evermore absorbs from the air carbonic acid, and returns to it pure oxygen in the daytime. The decay of organic matter, vegetable and animal, generates numer-

ous substances which are prejudicial to health. LIEBIG has lately shown that ammonia from these sources is continually present in the air. Its quantity is so minute that it cannot be directly detected, but it may be traced in rainwater, having been washed out of the air in its descent (371). The exhalations and effluvia arising from active decomposition in wet lands, swamps, marshes, &c., especially in hot seasons and localities, are prolific sources of disease. Minute microscopic germs, both vegetable and animal, exist in the atmosphere, and the course of winds has been tracked across oceans by the peculiar organic dust which they carried. Not only do plants and flowers exhale continually their peculiar fragrances, but even mineral matters and earths have also their odors, which rise and mingle with the air. Indeed, we must conceive of the air as the grand reservoir into which all volatile matters escape. Professor GRAHAM contends that malarious and contagious bodies are not strictly gaseous, but are highly organized particles of fixed or solid matter, which find their way into the atmosphere, like the pollen of flowers, and remain for a time suspended in it. The inconceivable minuteness of exhalations diffused through the air, which are yet sufficiently active to impress the senses, is forcibly illustrated by the following fact, which we give on the authority of Dr. CARPENTER. "A grain of musk has been kept freely exposed to the air of a room, of which the doors and windows were constantly open for a period of ten years, during all which time the air, though constantly changed, was completely impregnated with the odor of musk; and yet, at the end of that time, the particle was found not to have sensibly diminished in weight."

300. **Effects of Exposure, Foliage, and Soil.**—The salubrity of the external air is influenced by elevation, trees, and soil. The exposed hilltop ensures atmospheric purity. It is often surprising what effect a small difference in the elevation has upon the healthfulness of a particular spot. A rise of 16 feet within 300 yards has been known to produce an entire change from a relaxing to a bracing air. The lower place was completely enveloped in foliage and without drainage, while the higher was comparatively free from trees, and besides, had a good fall for surface-water and sewerage. Dense foliage around a dwelling may be injurious, by causing dampness and stagnation of air, especially if the situation be protected from winds. If the ground be loaded with putrefying matter and soaked with refuse water, the air above it cannot be pure. The ground below and around the dwelling should be dry. A soil absorbent and retentive of moisture, always damp, is

unfit to live on unless thoroughly drained. Sand or gravelly ground is best, provided it be not locked in by a surrounding clay basin, with no outlet for the rainfall.

301. **Cause of the unwholesomeness of Night Air.**—There is ground for the common belief that night air is less healthful than that of the day. It is known that the deadly tropical fevers affect persons almost only during the night. Yet the poisonous miasms from the rotting substances of the ground which cause those fevers, is produced much faster during the intense heat of the day than in the colder night. But in the daytime, under the hot tropical sun, the air heated by contact with the burning ground expands and rises in an upward current, thus diluting and carrying away the poisonous malaria as fast as it is set free. The invisible seeds of pestilence, as they ripen in the festering earth, are lifted and dispersed in the daytime by solar heat; but as no such force is at work at night, they then accumulate and condense in the lower layer of the atmosphere. Now although fatal fever poison may not be generated, yet decomposition of vegetable matter yielding products which are detrimental to health take place every where upon the surface of the ground; and though dissipated during the day, they are concentrated and confined so close to the earth at night as to affect the breathing stratum of the air.

302. **Upper Rooms least affected by Night Air.**—It will hence be seen that the different stories of a house are differently related to this source of injury: the upper ones being situated above the unwholesome zone, are most eligible for sleeping chambers, while the ground-floor is more directly exposed to the danger. Dr. Rush states, that during the prevalence of yellow fever in Philadelphia, those who occupied apartments in the third story were far less liable to attack than those who resided lower. Low one-story houses, in which the inhabitants sleep but three or four feet from the ground, and are therefore directly exposed to the terrestrial exhalations, must be considered more objectionable than loftier sleeping apartments. Sleeping in low rooms is perhaps worse in the city than in the country.

303. **The Atmosphere Self-purifying.**—In all healthy localities the proportion of impurities is so small that their effect is imperceptible. When noxious exhalations are set free from any source, they are diffused through the vast volume of the atmosphere, so as not to be detectable by the most refined means of chemistry. The law of gaseous diffusion, aided by winds and storms, secures dispersion and universal intermixture. Oxygen finally takes effect upon these baneful emanations, destroying and burning them as truly as if they had been

consumed in a furnace. The atmosphere thus secures its own purification on the grandest scale, and its vital relation to animal life remains undisturbed.

304. **Air within Doors.**—But when we enter a dwelling the case is altered. It is as if the boundless atmosphere had ceased to exist, or had been contracted within the walls of the apartment we occupy. Causes of impurity now become a matter of serious consideration. They are capable of affecting, in the most injurious manner, the little stock of air in which we are confined; and it is therefore, on every account, important that we have a clear idea of the nature and extent of the common causes which vitiate the air of our dwellings.

IV.—SOURCES OF IMPURE AIR IN DWELLINGS.

305. **Breathing and Combustion.**—By breathing, the burning of fuel and combustion for light, large quantities of oxygen are removed from the air, while at the same time carbonic acid in nearly equal bulk takes its place. In the case of fuel, if the combustion is perfect, the air that has been changed is immediately removed up chimney by the draught. But not so in respiration and illumination; the air spoiled by these processes remains in the room, unless removed by special ventilating arrangements.

306. **Leakage of bad Gases from Heating Apparatus.**—While, in point of economy, stoves are most advantageous sources of heat, yet in their effects upon the air they are perhaps the worst. We saw that in the stoves called *air-tight*, the burning is carried on in such a way that peculiar gaseous products are generated (121). These are liable to leak through the crevices and joinings into the room. Carbonic oxide gas is formed under these circumstances, and recent experiments have shown that it is a much more deadly poison than carbonic acid. The slow, half-smothered burning of these stoves requires a feeble draught, which does not favor the rapid removal of injurious fumes. Besides, carbonic acid being about half as heavy again as common air, must be heated 250° above the surrounding medium to become equally light, and still higher before it will ascend the pipe or flue. If the combustion of the fuel is not vivid, and the draught brisk, there will be regurgitation of this gaseous poison into the apartment. Dr. Ure says, "I have recently performed some careful experiments upon this subject, and find that when the fuel is burning so slowly as not to heat the iron surface above 250° or 300°, *there is a constant deflux of carbonic acid into the room.*" Probably all stoves, from their imperfect

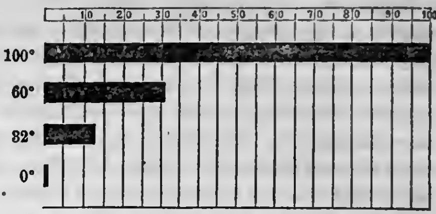
fittings, are liable to this bad result. Hot-air furnaces, also, have the same defect. They are cast in many pieces, and however perfect the joinings may be at first, they cannot long be kept air-tight, in consequence of the unequal contraction and expansion of the different parts under great alterations of heat. Combustion products are hence liable to mingle with the stream of air sent into the room.

307. **Air affected by Hot-iron Surfaces.**—But if stoves become a source of contamination to the air at low temperatures, neither are they free from this objection when made hotter; at high heats (and they are often red-hot), they seriously injure it in other ways. It is well known that iron highly heated causes disagreeable effects upon the air of rooms, producing a sensation ascribed to *burnt air*, but the nature of this change is not fully understood. The common method of explaining it, that the iron decomposes the air and robs it of oxygen, is in no degree satisfactory, as the quantity of oxygen thus removed must be extremely small, and besides, a portion of this very small amount comes from the decomposition of atmospheric moisture, its hydrogen being set free. The minute particles of dust, myriads of which fill the air, as seen when a ray of light is admitted into a darkened room, and which consist of all kinds of vegetable and animal matters, settle upon the hot stove, and are roasted or burnt with the escape of gaseous impurities. In the stove metal itself there is always, beside the cast-iron, more or less carbon, sulphur, phosphorus and arsenic, and it is possible that the smell of air, passed over it in the red-hot state, may be owing to the volatilization or escape of some of these; because it is to be remembered that a quantity of noxious effluvia, too small to be seized and measured by chemical means, may yet affect the sense of smell and the pulmonary organs.

308. **Composition of Air altered by heating it.**—It is a capital advantage of the methods of warming by fireplaces and grates—simple radiation—that they do not heat the air: it remains cool while the heat rays *dart through it* to warm any objects upon which they fall. The sun pours his floods of heat through the atmosphere without warming it a particle. Air is made to be *breathed*, and we again discover Providential Wisdom in the arrangement by which the sun warms us, without disturbing, in the slightest degree, the respiratory medium. But if we heat the *air itself*, we at once destroy the natural equilibrium of its composition, and so change its properties that it becomes more or less unpleasant and prejudicial to health. We have noticed the bad effects upon the system of dry heated air, and it was shown that the state of dryness does not depend upon the actual

amount of moisture present, but upon the *temperature.* With the *same quantity of aqueous vapor*, it will be moist and humid at a low temperature, while at a high one it will be parched and greedy of water. The accompanying diagram (Fig. 71) exhibits the relative amount of moisture that air contains when saturated at the temperatures mentioned. Suppose that air at 32° be heated to 100° (and it often is much higher), and be then thrown into the room. The difference in the length of the bars opposite these two numbers expresses its deficiency of moisture, and hence its drying and parching power. Air thus changed is apt to produce unpleasant feelings and painful sensations in the chest, which are often attributed to too great heat. "In very dry air the insensible perspiration will be increased, and as it is a true evaporation it will generate cold proportional to its amount (69). Those parts of the body which are most insulated in the air, and furthest from the heart, will feel this refrigerating influence most powerfully; hence that coldness of the hands and feet so often experienced. The brain being screened by the skull from this evaporating influence, will remain relatively hot, and will get surcharged besides with the fluids which are expelled from the extremities, by the contraction of the blood-vessels caused by cold." In close rooms, not well ventilated, stoves exert this baneful influence upon the air in an eminent degree. This objection lies against *heated air*, no matter how heated. Stoves and air-furnaces, with their red-hot surfaces, are undoubtedly worse for the air than hot-water apparatus, which never scorch it; yet they, too, may pour into our apartments a withering blast of air at 150°, which may be potent for mischief. The only way that hot-air can be made healthful and desirable is by an effectual plan of artificial evaporation, which will be noticed among the means of preserving atmospheric purity (347).

FIG. 71.



The length of the bars indicates the relative proportions of moisture that a cubic foot of air will hold at the different temperatures.

309. **Contamination of Air from the Human Being.**—It is a common belief that the human system is distinguished by its vital power of resisting, during life, the physical agents which would destroy it; but that after death it is abandoned to these forces, and falls quickly into

putrefaction. This is an error. Under the influence of physical agency decomposition is constantly going on throughout the body, and is indeed the fundamental condition of its life (624). There is the same decay and chemical decomposition taking place in the animal fabric during life as after death; the difference being, that in the dead body the decomposing changes speedily spread throughout the mass, while in the living system they are limited and regulated, and provision is made for the incessant and swift expulsion of those effete and poisonous products of change, which if retained within the organism for but the shortest time, would destroy it. Streams of subtile and almost intangible putrescent matter are, all through life, exhaling from each living animal body into the air. The fluid thrown from the lungs and skin is not pure water. It not only holds in solution carbonic acid, but it contains also *animal matter*, the exact nature of which has not been determined. From recent inquiries, it appears to be an albuminous substance in a state of decomposition. If the fluid be kept in a closed vessel, and be exposed to an elevated temperature, a very evident putrid odor is exhaled by it. LEBLANC states that the odor of the air at the top of the ventilator of a crowded room, is of so obnoxious a character that it is dangerous to be exposed to it, even for a short time. If this air be passed through pure water, the water soon exhibits all the phenomena of putrefactive fermentation.

310. **Dr. Faraday's Testimony upon this point.**—"Air feels unpleasant in the breathing cavities including the mouth and nostrils, not merely from the absence of oxygen, the presence of carbonic acid, or the elevation of the temperature, *but from other causes depending on matters communicated to it from the human being.* I think an individual may find a decided difference in his feelings when making part of a large company, from what he does when one of a small number of persons, and yet the thermometer give the same indication. When I am one of a large number of persons, I feel an oppressive sensation of closeness, notwithstanding the temperature may be about 60° or 65°, which I do not feel in a small company at the same temperature, and which I cannot refer altogether to the absorption of oxygen, or the inhalation of carbonic acid, and probably *depends upon the effluvia from the many present;* but with me it is much diminished by a lowering of the temperature, and the sensations become more like those occurring in a small company."

311. **Air of Bedrooms.**—The escape of offensive matters from the living person becomes most obvious when from the pure air we enter an unventilated bedroom in the morning, where one or two have slept

the night before. Every one must have experienced the sickening and disgusting odor upon going into such a room, though its occupants themselves do not recognize it. The nose, although an organ of exquisite sensibility, and capable of perceiving the presence of offensive matters where the most delicate chemical tests fail, is nevertheless easily blunted, and what at the first impression feels pre-eminently disgusting, quickly becomes inoffensive. Two persons occupying a bed for eight hours, impart to the sheets by insensible perspiration, and to the air by breathing, a pound of watery vapor charged with latent animal poison. Where the air in other inhabited rooms is not often changed, the water of exhalation thus loaded with impurities, condenses upon the furniture, windows, and walls, dampening their surfaces and running down in unwholesome streams.

312. **Purity the Intention of Nature.**—Yet we are not to regard the human body as necessarily impure, or a focus of repulsive emanations. The infinite care of the Creator is seen nowhere more conspicuously than in the admirable provision made for the removal of waste matters from the system, the form in which they are expelled, and the prompt and certain means by which nature is ready to make them inoffensive and innoxious. "The skin is not only," as BICHAT eloquently observes, "a sensitive limit placed on the boundaries of man's soul, with which external forms constantly come in contact to establish the connections of his animal life, and thus bind his existence to all that surrounds him;" it is at the same time throughout its whole extent densely crowded with pores, through which the waste substances of the system momentarily escape in an insensible and inoffensive form, to be at once dissolved and lost in the air *if this result be allowed.* It is not by the natural and necessary working of the vital machinery that the air is poisoned, but by its artificial confinement and the accumulation of deleterious substances. If evil results, man alone is responsible.

313. **Other sources of Impurity.**—Gaseous exhalations of every sort escape from the kitchen, and are diffused through the house as their odors attest, and the darkening of walls and wood-work painted with white lead shows that poisonous sulphuretted hydrogen from some source has been thrown into the air, its sulphur combining with the lead and forming black sulphuret of lead.* From the imperfect combustion of oil and tallow for lighting, and the defective burning of gas jets there arise emanations often most injurious to health. The vapor of a smoky lamp, if disengaged in small quantities, and the fumes of the burning snuff of a candle, may fill the room with disgusting odors

* White zinc paint does not thus turn black.

and excite severe headache. It may be well here to correct the common fallacy that cold air is therefore pure, and that apartments need less ventilation in winter than in summer. People confound coolness with freshness, and disagreeable warmth with chemical impurity; whereas these properties have necessarily nothing to do with each other. Cold air may be irrespirable from contamination and warm air entirely pure.

314. **Poisonous Colors on Paper Hangings.**—Attention has lately been called to the poisonous influence of green paper hangings upon the air. Cases are mentioned of children poisoned by chewing green colored hanging paper, and of persons sickened by breathing air in rooms in which certain green papers have been mounted. The basis of the bright green colors used for staining paper-hangings is the poisonous *arsenite of copper*, a combination of arsenic and copper. This, however, is not volatile, and does not create poisonous fumes or vapors, unless perhaps by being dusted fine particles are loosened and set afloat in the air. Nevertheless, though it do not vaporize and get into our systems through the lungs, *arsenite of copper* is a deadly poison, and when spread over paper-hangings, utterly spoils them *for dietetical purposes*, either for children or adults. Professor Johnson, of New Haven, states that the most beautiful of all green pigments is the *aceto-arsenite of copper*, and that this compound, in damp weather and humid situations, exhales deadly poisonous vapors supposed to contain arsenuretted hydrogen. This gentleman has given an account of a family poisoned by sleeping in a room where the paper was colored with this pigment.

315. **Foul Air generated in Cellars.**—The air in our houses is also liable to contamination from various organic decompositions, if vigilant precaution is not taken to prevent it. Cellars are commonly converted into reservoirs of pernicious airs, by the reprehensible custom of using them as receptacles for the most perishable products. But even where large masses of organic matter are not left to undergo putrefactive decay, and generate unwholesome miasms, serious injury is liable to occur from the damp and stagnant air of basements and cellars. It is not necessary that the lower spaces of a house should be half filled with rotting garbage to generate foul air. The surface of the earth is filled with decomposable substances, and whenever air is confined in any spot in contact with the ground, or any changeable organic matter, it becomes saturated with various exhalations which are detrimental to health. If air is to be confined, unless it is so sealed up as to touch nothing but dry, glassy or mineral substances,

it will certainly degenerate. Even dry rooms and closets in the upper part of the house, become mouldy and musty to a most disagreeable extent, if not often aired. To be pure and healthy, air requires continual circulation; but cellars are very rarely either ventilated or made absolutely dry by water-proof walls or floors. They are usually damp, cold, uncleanly, and mouldy. "The noxious air generated in cellars, basements, and under-floor spaces, reaches the inhabitants of upper apartments in so small quantities, that instead of producing any marked and sudden process of disease, it operates rather as a steady tax upon their income of health; so uniform in its depressing effects as not to be appreciated. Yet many an invalid, who fancies himself improved by a change of air, in going to another residence, is really relieved by escaping the mouldy atmosphere which comes from beneath his own ground-floor." *

V. MORBID AND FATAL EFFECTS OF IMPURE AIR.

316. **Sources of danger in Breathing**—The constituent of the atmosphere are mingled in such perfect proportions, that its temper is exactly suited to the necessities of the healthy system; any alteration in its composition, therefore, however slight, must result in physiological disturbance. So direct is the access that respiration affords, to the inmost recesses of the body, that any gas mingled with the respired air, is at once admitted, and takes prompt control of the system. When aliment is taken into the stomach, it is submitted to a long process of preparation and sifting, before it can gain admission to the blood, those parts which are useless or obnoxious being rejected;

* "The reports of the Registrar-Genera. of England disclose to us some very startling facts in reference to the slow influences of different states of air in affecting length of life. If any one were to select from among all the different occupations the healthiest men of a nation, he would probably choose the farmers and the butchers. Both are usually stout in frame, and ruddy in complexion. Both are actively employed, have plenty of exercise and abundance of food. In one point, therefore, their circumstances widely differ. The farmer breathes the pure air of the country; the butcher inhales the atmosphere of the shambles and the slaughter-house, tainted with putrefying animal effluvia. The result is an instructive lesson as to the value of pure air. The rate of deaths stated among the farmers, between the ages of 45 and 55, was 11·99 per thousand (annually). The butchers at the same age died at 23·1 per thousand, so that their mortality is about double that of the farmers. These two classes, indeed, occupy nearly the extremes of the table of mortality. The farmer is the healthiest man on the list, while there is but one worse off than the butcher—the innkeeper. Any one who knows how large a proportion of taverns are mere grogshops, reeking with impurities and environed in filth, will not be surprised that the mortality among this class ascends to 28·34 in the thousand."

but the lungs exercise no such protective or selective power, they cannot guard the system by straining the air, or barring out its injurious gases. Besides, air both pure and impure is alike transparent and invisible, so that the eye cannot detect the difference. The causes of vitiation are also gradual and insidious in their action, so that their effects steal imperceptibly over the system. Unlike heat, deleterious air announces its presence by no sensation; indeed, its effects are of that stupefying kind that makes a person insensible to them. A bedroom, as we before remarked, may be so foul from loathsome exhalations, as to nauseate a person who enters it from the pure air, and yet its inmates will feel quite unconscious of any thing disagreeable. Without intelligent and thoughtful precaution, therefore, we are constantly liable to the evil effects of foul air, and to imminent danger from various forms of disease.

317. **The System prepared to receive Contagion.**—Respiration of impure air, is a prolific source of disease, which appears in numerous forms and all degrees of malignity. The effect of breathing a confined and unrenewed atmosphere, is not only to taint the air, but by a double influence, to taint also the blood. It is an office of oxygen in the body, as we have seen, to throw the products of waste into a soluble state that they may be readily excreted, bnt if its quantity be diminished in the air, this work is imperfectly performed in the body; and the vital current is encumbered with putrescent matter. The increase of carbonic acid in the air, by offering a barrier to exhalation from the lungs, conspires to the same result. Accumulation of these morbid products in the blood, greatly heightens its susceptibility of being acted upon by atmospheric malaria, the causes of epidemics. The blood is supposed, under these circumstances, to acquire a fermentable state, forming, as it were, a ready prepared soil for the seeds of infection. Atmospheric malaria seem not capable *alone* of producing epidemic disease. From those in real robust health, with perfect sanative surroundings, the arrows of contagion rebound harmless. The miasmatic poison *must find some morbidity in the system to co-operate with*,—some unhealthy condition induced by intemperence or debauchery, bad food or drink, bodily exhaustion, mental depression, or the discomforts of poverty—upon which it may take effect. But of all these predisposing agencies, none invite the stalking spectre of pestilence with so free and deadly a hospitality, as corrupt, contaminated air.

318. **Illustration in the case of Cholera.**—Of the tendency of an atmosphere charged with the emanations of the human body, to favor

the spread of contagious disease, the illustrations that might be quoted are innumerable. Take an instance of cholera, for example. It is well known to those who have had the largest opportunities of studying the conditions which predispose to this malady, that *overcrowding* is among the most potent. In the autumn of 1849, a sudden and violent outbreak of cholera occurred in the workhouse of the town of Taunton (England), no case of cholera having previously existed, and none subsequently presenting itself among the inhabitants of the town, though there was considerable diarrhœa. The building was badly constructed, and the ventilation deficient; but this was especially the case with the school-rooms, *there being only about* 68 *cubic feet of air for each girl*, and even less for the boys. On Nov. 3d one of the inmates was attacked with the disease; in ten minutes from the time of the seizure, the sufferer passed into a state of hopeless collapse. Within the space of 48 hours, from the first attack, 42 cases and 19 deaths took place; and in the course of one week, 60 of the inmates, or nearly 22 per cent. of the entire number were carried off; whilst almost every one of the survivors suffered more or less, from cholera or diarrhœa. Among the fatal cases were those of 25 girls and 9 boys, and the comparative immunity of the latter, notwithstanding the yet more limited dimensions of their school-room, affords a remarkable confirmation of the principle we are indicating, for we learn that "*although good and obedient in other respects, the boys could not be kept from breaking the windows*," so that many of them probably owed their lives to the better ventilation thus established. In the jail of the same town, in which every prisoner was allowed from 800 to 900 cubic feet of air, and this continually renewed by an effcient system of ventilation, there was not the slightest indication of the epidemic influence. (Dr. CARPENTER.) It is in confined spaces thus charged with putrescent bodily exhalations, that pestilence revels; they resemble in fatality those localities where the air is poisoned by effluvia from foul drains, sewer-vents, slaughter-houses, and manure manufactories.

319. **Fevers originate in Impure Air.**—As with cholera, so also with fevers; foul air not only augments their malignity, but also calls them into existence. Writers on pestilence, observes Dr. GRISCOM, note two distinct species of virus applied to the body, through the medium of the air. First, that arising from the putrefaction of dead animal and vegetable matter—the accumulations of filth around dwellings and in cities, and the exhalations of swamps, grave-yards, and sewers, called *marsh miasm.* This is supposed to give rise to yellow, remittent, bilious,

and intermittent fevers, dysentery, and perhaps also cholera. And second, exhalations from the human body, confined and accumulated in ill-ventilated habitations, sometimes termed *typhoid miasm*, and which usually gives origin to common typhus and low nervous fevers. It would thus appear, that the very type and character of febrile disease is determined by the *kind of impurity* which is breathed. Prof. Smith, of New York, says, "Let us suppose the circumstances in which typhus originates, to occur in summer, such as the crowding of individuals into small apartments badly ventilated, and rendered offensive by personal and domestic filth; these causes would obviously produce typhus in its ordinary form. But, suppose there exist at the same time, those exhalations which occasion plague, and yellow fever, or remittent and intermittent fevers; under such circumstances we would not expect to see any one of those diseases fully and distinctly formed, but a disease of a new and modified character. It is, therefore, beyond probability that a few deleterious gases are quite sufficient to produce an infinite variety of pestilential and contagious maladies."

320. **Scrofula, or Struma, the consequence of Impure Air.**—There is a diseased condition of body known as *scrofulous* or *strumous*, which manifests itself in various forms, and in all parts of the system. It seems to be a result of deficient nutrition; that is, not a want of material for nutricious purposes, but a failure of power to produce healthy and perfect tissue from the elements of food. Various causes have been assigned as tending to produce scrofulous habits of body, such as hereditary tendency, bad diet, depressing passions, too late, too early, or in-and-in marriages, sedentary occupations, want of exercise, deficient clothing, bad water, &c., and these, under different circumstances, may each contribute to the result; but imperfect respiration is probably the most efficient and universal cause. An eminent French Physician,* who has made this subject a matter of extensive study, says, "Invariably it will be found on examination, that a truly scrofulous disease is caused by a vitiated air, and it is not always necessary that there should have been a prolonged stay in such an atmosphere. Often a few hours each day is sufficient, and it is thus that persons may live in the most healthy country, pass the greater part of the day in the open air, and yet become scrofulous, because of sleeping in a confined place, where the air has not been renewed." The same observer goes further, and affirms that the repeated respiration of the same atmosphere, is a primary and efficient cause of scrofula, and

* M. Baudoloque.

that, "if there be entirely pure air, there may be bad food, bad clothing, and want of personal cleanliness, but that scrofulous disease cannot exist." In 1832, at Norwood School in England, where there were 600 pupils, scrofula broke out extensively among the children, and carried off great numbers. This was ascribed to bad and inefficient food. Dr. Arnott was employed to investigate the matter, and immediately decided that the food "was most abundant and good," assigning "defective ventilation, and consequent atmospheric impurity" as the true cause.

321. **Consumption induced by Impure Air.**—When scrofula localizes itself in the lungs, there is *pulmonary* or *tubercular consumption.* The essence of the nutritive process consists in the vital transformation of albumen (678) into fibrin and organized tissue. Now the tubercles which in this disease make their appearance in the pulmonary organs, consist of crude, coagulated, half organized masses of albumen —the abortive products of incomplete nutrition. In this manner, bad air, by producing the strumous condition, becomes a cause of consumption. It seems natural to expect that the organs with which the foreign gaseous ingredients of the atmosphere come more immediately into contact, and whose blood-vessels they must enter on their passage into the system, should feel, in a distinctive manner, their noxious influence; and this expectation is strengthened by observation, and experiment upon both men and animals. It has been observed that when individuals habitually breathe impure air, and are exposed to the other debilitating causes which must always influence, more or less, the inhabitants of dark ill-ventilated dwellings, scrofula, and consumption, as one of its forms, are very apt to be engendered.

322. **State of the Air influences Infant Mortality.**—The same malign influence of the air of unventilated rooms is seen in the mortality of infants. That the new-born and tender child should be infinitely susceptible to the influence of contaminated air is what we might well expect. We are, therefore, not surprised, that in the foul and stifling air of Iceland habitations, two out of three of all the children should die before twelve days old. Opportunities have been afforded in hospitals, to compare the effects of pure and vitiated air, and it has been invariably found that a neglect of atmospheric conditions was accompanied by high rates of infant mortality, which promptly disappeared with the introduction of efficient ventilation. "On the imagination of mothers, educated as well as ignorant, the feeling still seems to be stereotyped, that the free, pure, unadulterated air of heaven falls upon

the brow of infancy as the poppies of eternal sleep, and enters the lungs and circulates as a deadly poison; and still the 'shawls and blankets,' sleeping and awake, are pretty generally employed to deprive the objects of the most rapturous paternal solicitude, of what was originally breathed into the nostrils of the great archetype of the human race as the 'breath of life.'"

323. **Bad Air undermines the Vital Powers.**—And yet the fatal effects of mephitic air are by no means confined to those terrible maladies, Cholera, Fevers, Consumption, and Infantine disease, by which the earth is ravaged; by undermining the health it paves the way for all kinds of disorders. The human system is armed with a wonderful protective or conservative power, by which it is able to resist the invasion of morbific agencies. Indeed, this power of resisting disease is perhaps a more correct measure of the real vigor of the body than its outward appearance of health. Individuals may often continue for years to breathe a most unwholesome atmosphere without apparent ill-effects; and when at last they yield, and are prostrated, or carried off by some sudden disease, the result is attributed to the more obvious cause, the long course of preparation for it by subtle and insidious poisoning being entirely overlooked. The mass of mankind refuse to recognize the action of silent, unseen causes. Our youth in the morning of their days, and men in the meridian of their strength, pass abruptly away, and we will be satisfied with no solution of the problem which refers the mournful result to reprehensible human agency.* "The action of contaminated confined air has been shown to be the most potent and insidious of mortiferous agencies. *Any* addition to the natural atmosphere that we breathe must be a deterioration, and absolutely noxious in a greater or less degree; and health

* "It is evident that the depressing effects of foul air are not confined to those cases in which the immediate results of its poison are seen. Because it requires a given quantity of carbonic acid in the air to exhibit decided effects, it does not follow that a much lower proportion does not seriously impair the vital energies, and especially the power of resisting disease. We are firmly convinced that many a case of scarlet fever or of measles proves fatal on account of an unperceived depression of the little sufferer's strength by previous continued exposure to an atmosphere tainted with carbonic acid and other exhalations from his own lungs. We know that all diseases of low grade, such as typhoid and typhus fever, prevail to a very great extent in ill ventilated houses; we know that an epidemic inflammation of the eyes has been frightfully prevalent in the Irish work-houses, and that it has been traced to imperfect ventilation, the eye-disease being merely the index of the general depression of the vital powers; we know, too, that in one of the Trans-Atlantic Hospitals, the mortality went down from forty in a thousand to nine, upon the adoption of a proper system of ventilation, and that it rose again to 24 on the subsequent abandonment of that system. These are only illustrations; hosts of similar facts could be cited from the records of medical science."

would immediately suffer, did not some vital conservative principle accommodate our functions to circumstances and situation. But this seems to get weaker from exertion. The more we draw on it, the less balance it leaves in our favor. The vital power, which in a more natural state would carry the body to seventy or eighty years, is prematurely exhausted, and like the gnomon shadow, whose motion no eye can perceive, but whose arrival at a certain point in a definite time is inevitable, the latent malaria, which year after year seems to inflict no perceptible injury, is yet hurrying the bulk of mankind, with undeviating, silent, accelerating rapidity, to an unripe grave. It should never be overlooked, that by breathing pent-up effete air, all the advantages of an abundance of fuel, and every blessing of a genial sky are utterly thrown away, and though the habitation were on the hill-top, fanned by the sweetest breezes of heaven, it would become the focus of contagious and loathsome disease, and of death in its most appalling aspect. On the other hand, even in the confined quarters of a crowded city, rife in malaria, and where pestilence is striking whole families and classes, ventilation and warmth, with cleanliness, their usual attendant, like the sprinklings on the lintels and door-posts of the Hebrew dwellings, stand as a sign for the destroying angel, as he passes over, to stay his hand, for in the warm, fresh-aired chamber none may be smitten."—(BERNAN.)

324. **Morbid Mental Effects of Bad Air.**—Dr. ROBERTSON remarks: "The health, the mental and bodily functions, the spirit, temper, disposition, the correctness of the judgment and brilliancy of the imagination depend directly upon pure air." This is strongly put, but it is not an overstatement. As the inflowing stream of air is the imminent and instant condition of physical life, so it is the immediate material agent charged with the exalted function of establishing and maintaining the connection of mind and body. It is air acting definitely and quantitively through the bodily mechanism, that sustains the order and activity of the mind's faculties. Mind is thus physiologically conditioned, and one of the mighty tasks to which science must gird itself in the future is to work out the analysis of these conditions. Mr. PAGET, the eminent English physiologist, remarks: "The health of the mind, so far as it is within our own control, is subject to the same laws as is the health of the body. For the brain, the organ of the mind, grows, and is maintained according to the same methods of nutrition as every other part of the body; it is supplied by the same blood, and through the blood, like any other part, may be affected for good or ill by the various physical influences to which it is exposed. But I will not

dwell on this more than to assert, as safely deducible from physiology, that no scheme of instruction or of legislation can avail for the improvement of the human mind, which does not provide with equal care for the well-being of the human body. Deprive men of fresh air and pure water, of the light of heaven, and of sufficient food and rest, and as surely as their bodies will become dwarfed, and pallid, and diseased, so surely will their minds degenerate in intellectual and moral power." The immediate effect of breathing impure air is to cloud the mind's clearness, to dull its sharpness, and depress its energy. All the mental movements are clogged, each faculty suffering restraint and perversion. The wings of the imagination are clipped, reason loses its keenness of penetration, and the judgment its acuteness of discernment and perspicacity. When we breathe bad air, the impressibility of the mind is diminished; if we undertake to study, we can neither understand so clearly, nor remember so well as if the air were pure. Socially we become less interesting, the spirits fall, conversation flags, dulness supervenes, we get impatient and irritable, and there is too often a resort in these circumstances to artificial exhilarants, and stimulants to afford relief, which would be better secured by freshness and purity of the atmosphere.

VI.—RATE OF CONTAMINATION WITHIN DOORS.

325. **Oxygen withdrawn by Respiration.**—Any scheme for the removal of foul air from an apartment, and the introduction of fresh air in its place, involves the previous inquiry, how rapidly ought this change to be made? Our next question, then, is at what rate does the air in dwellings become contaminated? The amount of air taken into the system by different individuals, varies greatly according to age, capacity of lungs, rate of exercise, and many other circumstances. Hence there is much discordance in the results of inquiries made by different physiologists. The disagreement is also much owing to the difficulties attending this kind of experimenting. If we take as the basis of our calculation COATHUPE's estimate, the lowest that we can find, we shall assume as an average, that there are 20 respirations in a minute, and at each respiration, 16 cubic inches of air pass in and out of the lungs. This is equal to 320 cubic inches per minute, 19,200 per hour, 460,800 cubic inches or $266\frac{2}{3}$ cubic feet per day of 24 hours. VIERORDT makes the quantity $306\frac{2}{3}$ cubic feet, SCHARLING 361 cubic feet; and VALENTIN as high as $398\frac{1}{2}$ cubic feet per day. As $\frac{1}{5}$ of the air is oxygen, there will be four cubic inches of this gas taken into the lungs at each inspiration. Of

this quantity, very nearly one half is absorbed and enters the blood. We may safely assume that 35 per cent. of the oxygen is thus absorbed at each breath, or 7 per cent. of the entire air. The quantity of oxygen consumed will be 22 to 24 cubic inches per minute, 1344 cubic inches or 3-4ths of a cubic foot per hour, and 18·6 cubic feet per day. A person, therefore, robs of *all* its oxygen nearly four cubic feet of air per hour, and diminishes its natural quantity 5 per cent. in 80 cubic feet per hour, or $1\frac{1}{3}$ cubic feet per minute.

326. **Proportion of Carbonic Acid exhaled by Respiration.**—When carbon is completely burned in pure oxygen, the carbonic acid gas produced occupies exactly the space that the oxygen did before burning. If all the oxygen absorbed by respiration was converted into carbonic acid in the system, the volume of this compound gas restored to the air would be exactly equivalent to the oxygen withdrawn. But a portion of oxygen unites with hydrogen and sulphur, forming water and sulphuric acid, while a small part of the carbonic acid generated within the body escapes into the air through the pores of the skin. The consequence is, that the bulk or volume of carbonic acid expelled from the lungs is not quite equal to that of the oxygen absorbed. Assuming the quantity of carbonic acid in the expired air to be 5 per cent., it will be one hundred times greater than the natural amount in the atmosphere (280). A person, therefore, by breathing adds 1 per cent. of carbonic acid to $55\frac{1}{2}$ cubic feet of air in an hour, or would vitiate to this extent nearly one cubic foot in a minute.

327. **Oxygen withdrawn by Combustion.**—The amount of combustion varies so widely with the kind of fuel used, the mode of burning it, the quantity of heat required, and other circumstances, that we can approach nothing like an average estimate of its influence upon the air in a given time. It is known with certainty how much oxygen given weights of the different fuels require for combustion, but the amount withdrawn from the air of a room depends entirely upon the rapidity with which it is consumed. A pound of mineral coal requires the oxygen of 120 cubic feet of air to burn it (90). If five pounds are consumed in an hour, at least 600 cubic feet of air must be removed from the room. Combustion of fuel, however, does not, like respiration, decompose the air, separating the life-sustaining element, and leaving the residue in the apartment. If properly conducted, it removes the air from the room unchanged, and having decomposed it in the fire, dismisses the contaminated product through the flue. Very often, however, when fires get low and draughts feeble, there is a refluence of foul gases into the apartment (121).

328. **Air vitiated by Illuminating Processes.**—The case is different when combustion is employed for illuminating purposes, as in the burning of candles, oil, and gas; these, like the body in respiration, alter the air *within* the room. A candle (six to the pound) will consume one-third of the oxygen from 10 cubic feet of air per hour, while oil lamps with large burners will change in the same way 70 feet per hour. As the degree of change in the air corresponds with the amount of light evolved, it is plain that gas-illumination alters the air most rapidly. A cubic foot of coal-gas consumes from 2 to $2\frac{1}{2}$ cubic feet of oxygen, and produces 1 to 2 cubic feet of carbonic acid. Thus every cubic foot of gas burned imparts to the atmosphere 1 cubic foot of carbonic acid, and charges 100 cubic feet with 1 per cent. of it, making it unfit to breathe. A burner which consumes 4 cubic feet of gas per hour, spoils the breathing qualities of 400 cubic feet of air in that time (224).

329. **Influence of Moisture upon the quantity of Air required.**—It has been noticed that air which is either very dry, or very moist and damp, is disagreeable and unwholesome. It should not contain so little moisture as to dry and stimulate the skin; nor so much that it will not readily receive the insensible perspiration which constantly flows to the surface. The amount of watery vapor emitted from the body has been stated at from 20 to 40 ounces per day. Estimates upon this point vary. If one of each sex be taken, the mean exhalation will be about 23 grains per minute. Now let us suppose the air of a room to be at 70°, and that it has to be cooled 20° before it begins to deposit moisture, that is, its dew-point is at 50°. The cubic foot of air at 50° contains 4·5 grains of moisture, and at 70° it will hold 8·4 grains, so that it is capable of dissolving 3·9, or nearly 4 grs. of water. Of air in this state, it will require about 6 cubic feet per minute to dissolve and remove the insensible perspiration from the skin. If the dew-point be lower, the air will take up more water, and less of it will be required to evaporate the moisture of the body. But if the dew-point be higher, the air will receive less moisture, and the system will require a larger supply. If the dew-point is at 60° and the temperature of the air at 70°, a cubic foot of it will become saturated by the addition of 2·17 grains, so that 10 feet per minute would hardly carry off the cutaneous exhalation. To be pleasant, air must not be deficient in moisture; if it be nearly saturated, it can imbibe but little, and consequently much of it must be brought in contact with the system; and this necessarily involves large provision for change of air.

330. **Air vitiated by one person in a minute.**—These sources of impurity are capable of measurement in their rate of effect, but there are other influences so irregular in action that the results they produce cannot be estimated. The whole quantity of air tainted by emanations from the person, and which requires removal, is variously stated by different authorities at from 3½ to 10 cubic feet per minute. We are of opinion, that for the restoration of its lost oxygen, the removal of carbonic acid, insensible perspiration, and the peculiar effluvia of the living body, there are required, at the lowest estimate, 4 cubic feet of air in a minute, or 240 per hour. But this may be much too low. It is evident that the nearer the air breathed within doors, approaches in purity and freshness to the free and open atmosphere, the better will it conduce to health, strength, and length of life. As far as possible we ought not to limit ourselves to that supply which the constitution can bear or tolerate, but to that amount which will sustain the highest state of health for the longest time. And yet, as Dr. Reid remarks, the question of the amount of air to be supplied may be considered in some respects in an economical point of view, in the same manner as the table any one can afford to sustain, the house in which he may dwell, or the clothing he may put on. Although pure air is the most abundant of all things, yet in our plans of living it is by no means free of cost (363).

331. **Influence of size of Apartments.**—The smaller an occupied room, the sooner, of course, will the stock of pure air contained in it be exhausted and replaced by foul air. Three persons sitting in a tight room 8 feet high, and 12 by 14 square, will vitiate all its air in two hours. If they use lights, the air will be spoiled much quicker. Twelve persons sitting in a parlor 16 by 20 and 9 feet high, will make its air unbreathable without the assistance of either fire or lights in a *single hour.* Two persons sleeping in a close bedroom 10 feet square by 8 high, will render all its air unfit for respiration in less than two hours. In actual practice, the cases are not quite so bad as this, for with the utmost perfection of carpentry there will be cracks for the passage of air, though perhaps in small quantities; and the opening and closing of doors cause intermixture and currents, and this somewhat delays the result. Where the rooms are capacious, the reservoirs of air are more slowly contaminated, and if no means are taken to remove the foul air and introduce that which is pure, large-sized rooms are of the utmost importance. But no apartments of ordinary or practicable dimensions will enclose sufficient air for the agreeable and wholesome use of their occupants. This must be attained in another way.

332. **Influence of Plants upon the Air of Rooms.**—The general action of plants upon the air is antagonist to that of animals. In the day-time, under the influence of light, they absorb carbonic acid from the atmosphere by their leaves, decompose it, and return pure oxygen to the air, thus tending by a double action to purify it. The rate at which these changes occur corresponds with the activity of growth. The plant, however, derives a portion of its carbonic acid from the soil, especially if it be rich, in decomposing organic matter, like the garden mould of flower-pots. Compared with the ordinary rate of contamination in occupied apartments, the purifying effect of the few green plants usually kept, is but small. In the absence of light, the peculiar actions of the leaves are suspended, nay, reversed; they now rather absorb oxygen, and give off carbonic acid, like ourselves. Hence, in sleeping-rooms, their tendency would be to impurity of the air, though the action is probably very slight. As respects moisture plants are also like animals, constantly exhaling it through the pores of their leaves. According to HALE's experiment, a sunflower weighing 3 lbs. exhaled from its leaves 30 ounces of water in a day. Plants may therefore be a useful means of supplying dry air with the requisite humidity.

VII.—AIR IN MOTION—CURRENTS—DRAUGHTS.

333. **Two methods of purifying the Air.**—Pure air may be secured in two ways: first and most perfectly by the removal of the vitiated atmosphere of the apartment, and its replacement by fresh air from out of doors. This is the mechanical method, and is known as *ventilation*,—a term derived from the Latin word signifying *wind.* The air may also be more or less perfectly cleansed by means of substances which absorb, decompose and destroy its noxious ingredients. This is the *chemical* method. It is useful only under certain circumstances, and is not applicable in common cases (802).

334. **Motive Power employed.**—As ventilation consists in the movement of masses of air, it implies some kind of moving force. On a large scale, as for public buildings, revolving fans, pumps, bellows, &c., driven by steam-engines or water-power, have been used to impart movement to air. But these contrivances are impracticable for dwellings. Wind power is often used as an aid in ventilation, but its unsteadiness prevents us from depending upon it. The force generally resorted to in private residences to secure exchange of air is *heat.*

335. **Currents of Air in Close Apartments.**—Changes of temperature externally give rise to unceasing commotions in the air—breezes, winds, and hurricanes. The same thing occurs within doors; any portion of air heated becomes lighter and causes an ascending current; any portion cooled becomes denser and causes a descending current. If a candle be lit in the middle of a room (Fig. 72) where the doors, windows and flues are closed, and the air is motionless, a set of currents will rise in the centre of the room, spread out near the wall, to its sides, then descend and return along the floor to the centre again. The arrows in the diagram show the direction of the currents in a *section* of the apartment. Fig. 73 shows the direction of the currents along the floor, that is, on a *plan*, as it is termed. If the arrows (Fig. 73) were reversed, they would show the course of the currents at the top of the room. If a lump of ice be substituted for the candle, currents are again produced, but they are exactly reversed in direction (352). The air descends from the cold ice, and the currents on the floor run outwards. In each of these cases, the currents above and below are opposite. All local disturbances of temperature tend to produce similar effects, although the currents are commonly much interrupted by disturbing forces. Of course several lights would occasion several currents, which would mutually interfere with each other. A stove in the centre of the room produces just such a movement of air as we have seen established by the candle; but if placed at one side, the hot-air ascends on that side and descends on the opposite.

FIG. 72.

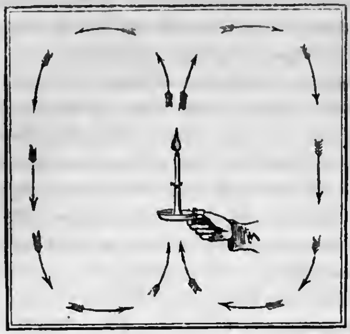
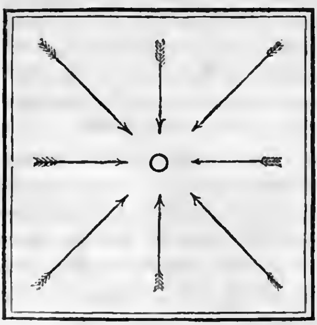


FIG. 73.

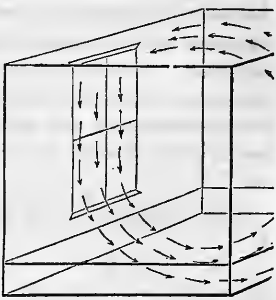


336. **Natural Ventilation of the Person.**—The warmth of the human body imparts itself to the layer of surrounding air, expands it, and

causes a rising current (107). When the temperature of the room is 65°, the body is 33° warmer, while 4° added to the circumjacent air will cause it to ascend and escape above the head. The simple presence of an individual in a room is therefore sufficient to throw the air into movement and cause currents. The body thus acts precisely in the same way as a stove, and the presence of persons distributed through a room will add much complexity to the movements of the air, and to a small extent counteract the stove-currents.

337. **Windows, though tight, produce Currents.**—Windows, in cold weather, though entirely tight, so that no air passes their crevices, are always sources of descending currents of air, with a corresponding ascending movement (Fig. 74). When between the internal warm air and the external cold air there is only one thin film of window-glass, the heat escapes through it so fast that the air within is rapidly cooled, condensed, and becomes heavier, so that a sheet of it is constantly falling to the floor. This cascade of cold air is frequently so sensible in winter that persons are apt to suppose it comes from some opening about the window. These winter window currents are often most injurious. If there be draughts through the room, produced by a fire or any other cause, they throw the window current out of its direction more or less to one side, so as frequently to fall upon persons who suppose themselves to be safely away from any such source of discomfort. Large windows in public rooms, in winter, should on this account be carefully avoided, as the cataract of cold air which they pour down upon the body is a frequent cause of rheumatism, colds, and inflammations. Such sheets of air often fall with mischievous effect upon sleepers, where beds are placed near windows. It may be remarked that in summer these currents are reversed; the heat, passing from without through the window glass, rarefies the air in contact with it, which rises so that the current passes in a contrary direction (289).

Fig. 74.



Currents produced in winter by single windows.

338. **The Air of rooms arranged in strata.**—But the effect of currents is not to cause a perfect intermixture with uniformity in the condition of the air throughout the room. Indeed, the very cause that gives rise to them is the tendency of cold air to fall into the lower place,

while it presses upward that which is warm and lighter. Hence, notwithstanding its constant motion, the air is in fact arranged in layers or strata, according to its temperature, the hotter air collecting near the ceiling, and the layers decreasing in temperature downwards as was previously stated (125). The difference of these temperatures is sometimes so considerable that flies will continue to live in one stratum which would perish in another. Now the warm and rarefied air which rises to the upper part of the room contains also the impure air which has been generated within it. The breath which escapes from the lungs, 20° or 30° warmer than the surrounding air, slowly rises above the head, while ascending currents from the body carry upward all its exhalations (334). So also the heated poisonous products of illumination mount rapidly to the ceiling. The effect of currents is, to a certain extent, to diffuse the foul gases throughout the apartment, but chemical tests show the same *stratification* of *impurities* that the thermometer indicated in regard to heat, the best air being below and the worst above. In a room having a fireplace, the cold air may enter at the top and bottom of a window, fall towards the floor and move along near it to the flue, where it is discharged. In its progress, it may even blow strongly upon a bed made on the floor, while all the air above, enveloping a bedstead of ordinary height, remains loaded with carbonic acid and aqueous vapor. In all ordinary rooms the floor is swept by draughts of cold air, and is unfit for a sleeping place, *especially if the apartments have open fireplaces.*

339. **Simple openings do not produce Currents.**—If an apartment be opened to the external air, various movements are liable to occur, or there will be no motion at all, according to circumstances. It by no means follows that because a communication has been opened between a room and the outer air, therefore currents will set in and an active interchange take place. Air will not leap out of a bottle because we extract the cork, nor out of a window simply because we open it. Cur-

FIG. 75.

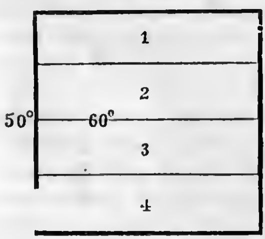
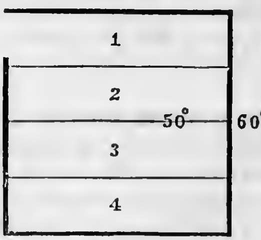


FIG. 76.

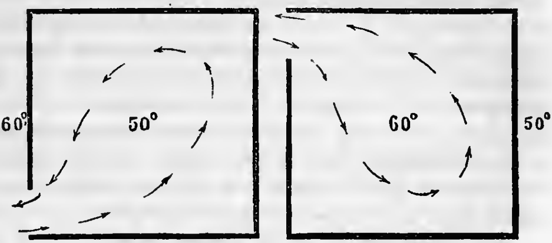


Conditions in which openings in rooms *do not* produce exchange of air.

rents cannot be produced unless their *causes* are brought into action. If a room be opened below, and the temperature within be higher than that without, as represented in Fig. 75, the outer, heavier air, pressing harder than that within, will confine it, no movement will take place, and the strata will retain their relative positions undisturbed, as in the figure; or, if the room be opened above, and the external air be warmer than the internal (Fig. 76), the lighter air without cannot press down to displace the inner, heavier air, which remains without movement or disturbance of its arrangement.

340. **Currents between rooms and external Air.**—If there be an opening at the lower part of a room, and the external air be warmer than that within, interchange takes place, the outward air displacing that within by currents running as the arrows show (Fig. 77), the heavier air within falling or flowing out. If the opening be above, and it be warmer inside than out, the light air inside will escape upward, and the cold, heavy air without flows in, as shown in Fig. 78. If there be but a single opening to a room, although all other conditions are favorable for a change, yet the counter currents meeting in the passage conflict, and to a certain extent obstruct each other. There should, therefore, be separate openings for currents of ingress and egress.

Fig. 77. Fig. 78.

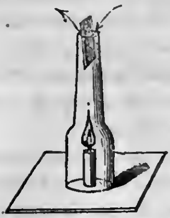


Conditions in which openings in rooms *produce* exchange of air.

341. **Friction of counter-currents of Air.**—The importance of having two independent openings to an apartment, if we desire to secure a change of air, is shown by the following simple experiment: Take a bottle with the bottom removed, or a lamp chimney (Fig 79), place under it a short piece of burning candle in a shallow dish of water, so that no air can get in from below; now, although the stopper be removed so that the inside of the bottle has direct communication with the outer air, the candle will go out. Although there is a tendency of the burnt air to escape and of the fresh air to rush in, yet they cannot pass each other at the open mouth; the currents conflict and the

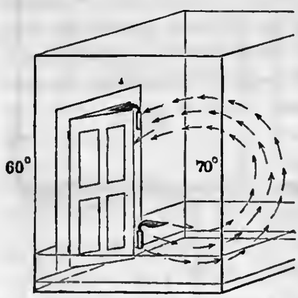
exchange does not take place. Yet, if a slip of paper be inserted in the mouth of the bottle or lamp-glass, as seen in Fig. 79, thus dividing it into two distinct apertures, the lit candle will continue to burn. The foul air will pass out on one side of the pasteboard and the pure air enter on the other, as may be shown by the smoke from the snuff of a candle held near; it will be drawn in on one side and carried up on the other. The purity of the air within is thus secured. When the opening, however, is sufficiently large, the currents pass without difficulty, as is easily illustrated. If the door of a warm apartment be opened, and a candle placed near it on the floor, the flame will be blown inwards; if it be raised nearly to the top of the door it will be blown outward, as illustrated in Fig. 80. The warm air flows out at the higher openings. If the air of the room be *warmer* than that without, it enters by all the crevices near the bottom, and escapes by those near the top, and the reverse if it be *colder*.

FIG. 79.



Effect of separating the air currents.

FIG. 80.

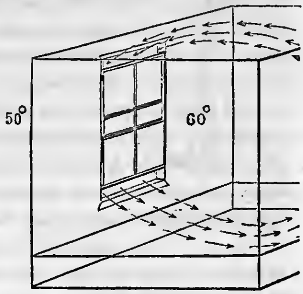


Counter-currents in the doorway.

342. **Currents through Windows.**—Draughts through windows and doors are often not effectual in removing all the air of rooms. In the case just instanced (Fig. 80), of the open door, the cold air below enters and expels an equal portion of the warmer air, but only that will flow out which lies below the level of the door-top. The mass of air above this level will not be displaced. If, however, the temperature of the room were at 60°, and that of the outer air at 70°, an open door would evacuate the room entirely of its airy contents; the colder air in the room tending to fall would pour out at the bottom, and the warm air enter at the top to take its place. If a window be situated in the upper part of the room and opened, its action is different, and in a manner opposite to that of the door. When the air is cold without and warm within, and the window opened above and below, the apartment is emptied and refilled as in Fig. 81. If the external air is warm and that within cool, all *above* the window sill is removed (Fig. 82), but the cold air below that level continues undisturbed. By thus understanding the

conditions of inflow and outflow, we are enabled to regulate windows having both sashes movable, and which are often valuable for ventilating private rooms. Although the interference of other causes is liable to modify, and perhaps often confuse and divert these movements, yet they are quite sufficient to show that the motion and rest of air are controlled by laws as definite and regular as those which govern the motion and rest of water. Though infinitely more light, mobile, and easily agitated, yet it is never thrown into commotion except by adequate and appreciable causes.

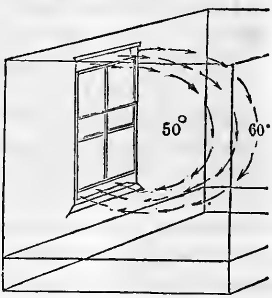
Fig. 81.



Condition in which the air escapes above.

343. **How currents of Air affect the System.**—The sensations produced upon the body by gently-moving currents of air in proper conditions of temperature and moisture are extremely agreeable, but in many cases streams of air directed against the person become most injurious. Air at low temperatures of course has a cooling effect. We lose no more heat by *radiation* in moving air than in still air, but by *conduction* we lose heat in proportion to the velocity of the current or the number of particles which come in contact with the body. The current also drives the cold air through the clothing, displacing the warm air which was entangled in its pores. Increased evaporation, proportional to the dryness and speed of the air, is also a further source of cold. If the whole surface of the body is exposed to the current, the effect will be simply a general cooling without any necessarily injurious effects. But if the draught fall only upon some one part of the body, it is liable to produce serious mischief, disturbing the circulation and producing febrile movements, which may be directed to the part exposed to the draught or even to remote organs, in either case often laying the foundation for serious and fatal disease. This point should be particularly considered in introducing air in summer which has been artificially cooled (352); its diffusion should be

Fig. 82.



Conditions in which the air escapes below.

very extensive and its velocity hardly perceptible. Of course we cannot have ventilation without movement of air, but the motion should be so moderated that we are not aware of it, and is always to be considered in connection with the two important conditions of temperature and moisture. We have made several trials to determine the velocity which, as a general rule, with a proper regard to other conditions, will not be found unpleasant, and give as the result about two feet per second. It is evidently no greater than that with which we should pass through still air when walking with the same velocity. (WYMAN.) Yet it is important that we be exposed to currents. Few things are more favorable to taking cold than the confined and stagnant air of unventilated apartments. Just in proportion as we habituate ourselves to such still, stagnant air, do we become sensitive to atmospheric changes, against which it is impossible perfectly to protect ourselves on going out. The effect of a free internal circulation of air in our rooms is therefore most salutary; the more we are accustomed to it, the safer we are in the vicissitudes of changing weather.

VIII.—ARRANGEMENTS FOR VENTILATION.

344. **The open Fireplace.**—The mechanical expedients for securing exchange of air in dwellings are numerous, but they are chiefly connected with arrangements for heating. Wherever there is active combustion in stove or fireplace, there must be a stream of air passing out of the room through the chimney. If the room be absolutely tight, so that no air can enter it, none will ascend, and if the fire be kindled the chimney will smoke. A draught through a chimney implies openings somewhere for air to enter the room, and thus there is some ventilation as a matter of necessity. In noticing the heating effect of the fireplace, we saw that the open space above the fire conveys away a large amount of warmed air from the room, which took no part in the combustion and wasted much heat. But this fault was an advantage in respect of ventilation. The magnitude of the open space above the fire represents the ventilating capacity of the chimney. But it is from the air below the level of the mantel—the purest in the apartment—that the fireplace is supplied. Only so much of the foul imprisoned air above as gradually cools and descends, being swept into the chimney. When the weather is quite cold, the briskness of the fire that is demanded, occasions a powerful draught and produces annoying currents. So powerful were these draughts in old times, that they were compelled to use a *settle*, a long bench with

a high wooden back, to protect the body from currents and retain the radiant heat in order to keep warm. "It would be well for those who question the importance of ventilation, because our forefathers lived to a good old age without even understanding the meaning of the word, to remember their fireplaces, the kind of dwellings they occupied, and the quantity of air which must have passed through their houses." It cannot be doubted that the changes which have of late years been effected in the structure of the fireplace to secure the greater economy of fuel—the contraction of its dimensions and the lowering of the chimney-piece, by diminishing the amount of air that was forced through the room to fill the capacious chimney, and by bringing the foul-air space down more completely within the zone of respiration—have been altogether unfavorable; although, even in their newer construction, open fires may be considered as affording a tolerable amount of ventilation. Fresh air is well secured by the double fireplace, which warms and introduces into the room a steady stream of air from without. (111.)

345. **Ventilation by Stoves.**—As respects the *condition* of the air, the exchange of even the low and contracted fireplace for the close and stifling stove, has been eminently promotive of discomfort and disease. Stoves afford the least ventilation of all our means of heating. They take little more air than just sufficient to consume the fuel, and that is withdrawn from the purer portion near the floor. In most cases of the use of stoves, no provision whatever is made for the removal of bad air. They may be made subservient to ventilation in several ways; first, by allowing air to pass through tubes in the body of the stove; second, by admitting it between the stove and an external casing; and third, by simply allowing it to strike upon the external surface of the stove. In either case the entering air will be warmed, rise toward the ceiling, and afterward gradually descend as the air below is drawn off, producing a downward ventilation through the whole apartment. Mr. Ruttan, of Coburg, C. W., has devised a plan of heating and ventilating, strongly recommended by those who have used it, although we have had no opportunity of seeing its operation. He locates his 'air-warmer' in the hall, or where required, brings in the air from below, heats and transmits it through the building. For the best working of his arrangement it is important that the house be built with reference to it; indeed, he insists that the general failure to ventilate is because the architects fail to provide the necessary *lungs* in the original construction of dwellings (362).

346. **Ventilation by Hot-Air Arrangements.**—Sources of warmth be-

come the most effective means of ventilation when air itself is made the vehicle for conveying heat into the room, as in the use of hot-water apparatus, furnaces, &c. The hot current enters through a register, or guarded opening, and streams up at once to the ceiling; and by diffusion through the apartment, displaces the air already present, which must find escape somewhere, and thus the renewal of the breathing medium is constantly secured. Apartments warmed in this manner require a chimney or other place by which air may escape. The fireplace answers perfectly; but under the impression that rooms heated by air-currents require no channel of escape, houses have been constructed with no flues at all. The air ought to be projected into the room horizontally or at different points, so as to be well diffused (125). It should always be derived from perfectly pure sources, and never used a second time. But the chief difficulty and danger, as before noticed, is to be found in that condition of the air itself, which results from its being suddenly heated (305).

347. **The supply of Moisture.**—The provision for supplying moisture by evaporation is rarely any thing like adequate, a supply of 35 cubic feet of air per minute introduced at the temperature of freezing and heated to 90°, is capable of taking up an ounce of water per minute, or four pounds in an hour. Dr. Reid states, that in ventilating the English House of Commons, when it was crowded, he often exposed the air furnished to 5,000 feet of evaporating surface, to impart the necessary moisture, *and subsequently made the air flow through jets of water.* The artificial supply of moisture to air in the exact quantity required, involves grave difficulties. The common method of supplying humidity by simmering water in an open vessel, is glaringly insufficient. A pan of water is placed in a furnace,* but of the torrent of air that rushes through, how little is brought into contact with the water. We place a vessel upon a stove with a few square inches of water-surface, and fancy all is right, but the air may still be parching dry. Where air in cold weather is introduced, suddenly rarefied by heat, and actively changing, we have little conception of the amount of moisture which must be artificially added to give to it soft and balmy qualities. The best thing to be done of course is, to obtain the largest possible evaporating surface. To accomplish this, a piece of linen or cotton cloth dipped in a vessel of water, may be hung in folds from any convenient framework or support. The cloth, by sponging

* Walker's furnace, manufactured by S. B. James, No. 77 White street, New York, has large provision for evaporation, which the proprietors offer to increase to any extent that individuals may demand.

up the water is always wet, and gives out its moisture to the air. If previously dipped into a solution of potash, which is very absorbent of water, it continues more perfectly wet. If it be unsightly, the suspended cloth may be concealed from view by any graceful screen, as by a tower-shaped cover of porcelain, open above and below to admit the passage of air. Where hot-air is used, it may even become necessary to mingle with it the vapor of boiling water.

348. **Best method of Warming and Ventilation.**—If we would have the pleasantest mode of warming and ventilating a dwelling-house, without regard to trouble or expense, we should certainly combine the open fireplace with air-heating apparatus, which should never exceed in temperature 212°. The first is desirable for its pleasant light and radiant heat, while the second gives to the entries and chambers a mild atmosphere, which prevents cold draughts from open doors, and at the same time, through an opening in each apartment, moderately warms it, and likewise supplies air for the ventilation going on by the fireplace. The fireplace also has its influence upon the introduction of the warmed air. The heat of the chimney establishes a current which draws from the air-heating apparatus a large supply of air at a lower temperature than would otherwise enter the apartment. We know of no single apparatus which warms and ventilates a dwelling-house in so healthy and comfortable a manner as is accomplished by this combination.—WYMAN. Yet it can only be had by very few; for the mass of the people it is entirely out of the question from expensiveness.

349. **Supply of Air by loose Joinings, Crevices, &c.**—Hot-air contrivances of any kind, although coming more into use, especially in cities, are by no means general. Grates and stoves are the nearly universal sources of heat, and the latter of these cannot be said to ventilate at all. No provision is made for the entrance and exit of air. The use of doors to rooms is for the admission of their occupants, windows are for the entrance of light, and it would certainly seem, both from its importance and peculiar properties, that *air* also is entitled to an entrance of its own. Yet in most cases we treat the air as if it had no business in our dwellings. It has to avail itself of the mechanics' botch-work or the chance shrinkages of time, and creep through any crevices and wind-chinks that there may happen to be, or dodge in and out at the casual opening of windows and doors. These cracks and loose joinings afford a kind of imperfect accidental ventilation, which, by effecting the purpose in a partial

degree, has prevented mankind from discovering the want of any thing better.

350. **Four points to be secured in Ventilation.**—That ventilation may be complete, and do for us its best service, four things must be attended to.

First. Pure air must be introduced.

Second. The foul air must be removed.

Third. The supply must be sufficiently copious.

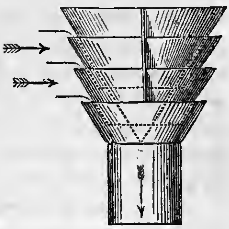
Fourth. There must be no offensive currents.

Now as things usually are, none of these points are certainly secured. There is no constant and regulated supply of air, this being left entirely to chance. There is no provision for the exit of the vitiated gases. All the air that is drawn off from the apartment is taken from its lower and purer portion by the draughts of the stove and fireplace, while that which *should* escape stagnates above. The quantity furnished is therefore variable and usually stinted, while injurious draughts are notoriously common. Independent and effective methods of changing the air, by which these enumerated benefits may be gained, are on every account desirable.

351. **Modes of introducing pure Air from without.**—In summer the free opening of doors and windows ensures a supply of air. It is a good plan to have light door-frames fitted to the outer entrances, and covered with wirecloth or some loose fabric, as *millinet*, through which the air will pass readily, but in a diffused manner. In winter the air should always, if possible, be warmed before being thrown into the apartment. For introducing more fresh air than accidental fissures will admit, the readiest way is to lower the top window sash, although the stream of cold air which presses in and is both unpleasant and unsafe, falls to the floor and glides to the stove or fireplace without being sufficiently commingled with the general atmosphere to serve the purpose of ventilation. It becomes a mere feeder of the fire. To disperse cold currents of air from above, a plate of zinc perforated with numerous holes is made to replace the pane of glass furthest from the fireplace and in the upper row of the window. *Louvres* made either of tin, zinc or glass, with horizontal openings and slats like Venetian blinds, are also substituted for window panes. A small tin wheel or whirligig, which revolves and scatters the inflowing current, is sometimes mounted in the window; it is often noisy and rattling. In arranging openings for the entrance of air, several circumstances are to be borne in mind. The air should always be fresh from without and not, as is too often done where hot-air furnaces are used,

taken from cellars or basements, or what is still worse, used over and over again. If there be local sources of impurity in the vicinity, apertures should not be placed favorably to its admission. Where dust is an annoyance, or from any cause there is contamination of air near the ground, the supply may be brought from the top of the house. Openings are made under the eaves, or in some eligible place near the summit, leading to channels left in the walls, called *fresh-air venti-ducts*, which pass down and open into the room in any convenient manner. The prevailing direction of the wind should also be noticed, as it is desirable to command its aid as far as possible in forcing air into the building. EMERSON'S injector (Fig. 83) causes a downward current from whatever quarter the wind may blow upon it. All outer apertures should be guarded with valves. Air entering them and led along proper passages, either in tin tubes or air-tight wooden boxes, is admitted into the room at various points. There may be an air passage made along behind the base or mop-board, communicating with the room by innumerable minute openings, through which the air passes. Or the inflowing currents may be received through registers or made to rise through small apertures in the floor.

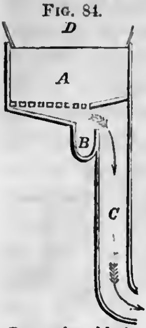
FIG. 83.



Emerson's Injector.

352. **The downward Current.**—Air once breathed must not be again brought within the sphere of respiration, but should it be removed downward or upward? The air thrown from the lungs escapes horizontally from the mouth and downward from the nostrils; it may then be swept without difficulty by the ventilating current in either direction. In cases where hot air is thrown into the room, it first rises to the ceiling, and then, as it is gradually cooled, falls, and is mainly drawn off by the fireplace below the plane of respiration. This is in effect a downward current, but it is hardly strong enough to carry the breath down with it. It ascends, is diluted by the upper air, and falling again is liable to be reinhaled. A descending current of air artificially cooled has been employed for ventilation; in fact, rooms can be as effectually ventilated in summer by the aid of coolers placed *above* them, as they are in winter by the heater *below* them. LYMAN'S ventilator (Fig. 84), consists of a reservoir of ice—A, the bottom of which is an open grate; B is a gutter to catch the water from the melting ice; C is a pipe or flue, through which a stream of cold condensed air falls constantly, as shown by the course of

Fig. 84.



Lyman's cold air flue.

the arrows; *D*, a wire gauze box filled with charcoal, which prevents the waste of ice by radiation, and disinfects and purifies the descending air. The force of the current depends on the length of the cold air flue and its temperature, compared with the outer air. In hot weather the breeze continues quite brisk. This arrangement, on a small scale, has been mounted on secretaries, to secure a cool and refreshing air while writing; over beds, to cool the air while sleeping; and over cradles, to furnish pure air for sick children (341).

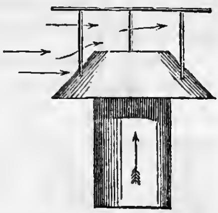
353. **The ascending Current most Natural.**—We have noticed that by a beautiful provision of nature, *ventilation of the person* is constantly taking place. The exquisite mechanism of the human system would have been created to little purpose if it had been left to smother in its own poison. A gentle and insensible current constantly rises from the body, which carries all that might be injurious into the higher spaces. Vitiated air would thus constantly escape from us if it could. But in our houses we defeat the benign intentions of nature by enclosing the spaces above us, so that the detrimental gases accumulate in the upper half of the room, surrounding the head and corrupting the respiratory fountain. It is thus evident that if we desire to aid nature in her plans, we must remove or puncture the air-tight covers of our apartments, so that the ascent and complete escape of foul air shall not be obstructed.

354. **Ventiducts and Ejectors.**—Openings for the escape of these bad gases above are indispensable. Each room fifteen feet square, for the accommodation of six or eight individuals, should have a flue for the escape of foul air, either in the chimney or elsewhere, of at least 100 inches area. A bedroom should have an outlet of nearly the same dimensions. But in practice a serious difficulty is encountered here. If we make an opening out from the top of the room, either by lowering the top sash of a window or by carrying up a duct through the roof, instead of the foul air escaping through them, a flood of cold air rushes in from without. Tubes or ventiducts, connecting the room with the top of the house, may be made to act exhaustively, and drain the apartment of its polluted air, *when the wind blows*, by surmounting it with Emerson's Ejector (Fig. 85), and as the air is almost constantly in more or less rapid motion, this arrangement becomes very serviceable.

355. **Opening into the Chimney—Arnott's Valve.**—But the force of

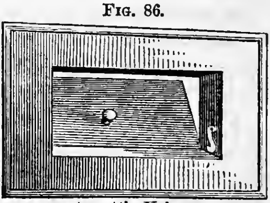
draught in the chimney is after all to be the main reliance in conveying away foul air. Its necessary action is that of a drawing or sucking pump, which exhausts the room of large quantities of air. As the velocity of smoke in a chimney with a good fire is estimated to be from 3 to 4 feet per second, its exhaustive power is amply sufficient to make it serve the secondary purpose of a ventilating flue. Hence, if we make a hole into the chimney, by knocking out two or three bricks near the ceiling, the foul gases will rush in, and mingling with the ascending current will escape. Yet these ventilating chimney openings are liable to the serious and even fatal objection, that when from any cause the current in the chimney is interrupted, smoke is driven into the room. An ordinary register, requiring personal attendance to open and close it, would be of no service. To remedy this inconvenience, Dr. Arnott has contrived a self-acting suspension valve. It is so placed in the aperture, and so mounted, that a current of air passing into the chimney opens it, while a current in the contrary direction closes it. It is so delicately suspended that the slightest breath of air presses it back, while any regurgitation of the chimney current shuts it, and thus prevents the backward flow of smoke into the room. It is shown in Fig. 86. Owing to the unsteadiness of the currents, the valve is constantly vibrating or trembling, and would be noisy but that it is made to strike against soft leather. A modification of this valve consists of a square piece of wire gauze set in the opening, with a curtain of oiled silk suspended behind it. The current into the chimney pushes back the pendant flap, while a reversed current drives it against the gauze, and thus closes the aperture against the admission of fire-fumes and smoke. These are easily placed in fire-boards used to close the fronts of chimneys.

Fig. 85.



Emerson's Ejector.

Fig. 86.



Arnott's Valve.

356. **Importance of Arnott's Valve.**—The value of this valve to the public can hardly be exaggerated. Mr. Tredgold expressed what many have felt, when he said that all the plans he had seen or read of for drawing off the air from the top of a room are objectionable, either from being wholly inefficient or from causing the chimney to smoke. This valve first meets the difficulty. It is cheap, easily inserted, may

be managed with trifling care, and drains the room effectively of its gaseous pollutions. In the thousands of stifling, stove-heated rooms, where palor of countenance, headache, and nervousness, bear painful witness to the perverted and poisoned state of the air, this simple mechanical contrivance might bring happy relief. It is much used in England, but has not been made sufficiently known in this country. We have inquired for it in vain at many establishments. It is manufactured by S. B. James & Co., 77 White street—price, $2 50 to $5, according to size. If the orifice in the chimney be deemed unsightly, it may be screened from view by placing a picture before it.

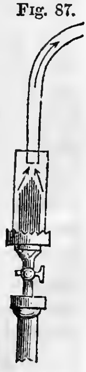
357. **Chimney Currents in Summer.**—The air in the chimney is usually somewhat warmer than the external air, even when there is no fire, and this will occasion a slight draught, so that if there be an aperture in the upper part of the room into the flue, and the fireplace be closed, the vitiated air above will be removed. This exhaustive action of the chimney without fire, is aided by winds blowing across its top, which exert a slight suction influence, or tendency to form a vacuum within it. This effect of the wind will be much increased if the chimney be mounted with an ejector (354). A slight fire in a fireplace, even when not wanted for warmth, is often desirable for ventilation. Lamps have been sometimes introduced into flues for the purpose of exciting currents.

358. **An additional Ventilating Flue.**—If an extra flue be constructed adjoining the chimney, warmed by it and opening into the top of the room, there will be a draught through it, and it may be devoted exclusively to ventilation. It would seem that such a secondary flue would not be liable to refluent smoke, and might have connected tubes extending to remote rooms, thus effectually ventilating the whole building. But practically such shafts do not well succeed. Double outlets in the same apartment rarely work satisfactorily. The chimney is liable to convert the extra flue into a feeder of the fire, and thus, if it be of the same height as the chimney, to suck back the smoke into the room. "Such cases have occurred, and the ventilating flue has been closed in consequence. This evil can be remedied by providing a free supply of air for both air and smoke flues. But the air which enters must be warmed, or it will not be tolerated, and if it is too much warmed, as compared with the air of the room, it will rise immediately to the ceiling and escape through the ventilator, and, not mingling with the air of the room, it will greatly diminish or entirely prevent any change of air where most wanted."

359. **Ventilation of Bedrooms.**—The bedroom, the place where we

spend nearly half of our lives, in its general condition and management is the opprobrium of civilization. No place in the house should be more copiously supplied with air to guard us against the injurious agencies to which we are nightly exposed. The materials of which bedding is composed have a strong tendency to attract moisture from the air and become damp. Not only are the textile fibres highly hygroscopic, or absorbent of atmospheric moisture, but the coldness of rooms in which beds are usually placed, favors the deposit of moisture when the air is charged with it. They are also saturated with bodily perspiration. Beds should, therefore, be often and thoroughly aired. Their injurious effects when damp are much more dangerous than those of wet clothes. As the body is at rest while we sleep, there is no exercise to warm the surface and throw off the ill effect, as can be done with damp clothes. Moreover, as the vital activity is depressed during the state of slumber, the system is more open to the malign influence of cold or other causes. Many and fatal diseases, inflammations, rheumatisms, catarrhs, asthmas, paralysis and consumption, are induced by a want of precaution in this particular. Yet with all these demands for capacious drying air-space, bedrooms are apt to be scandalously small and low, damp and unwholesome. They do not usually contain fireplaces to drain off the bad air, and the lack of all ventilation is made worse by the popular dread of draughts, which prevents the opening of windows. There is urgent necessity for the adoption of some means of relieving them. Opening the window above and below is very serviceable; lowering the upper sash, with an opening over the door, and currents in halls, also gives relief. But if the bedroom have no fireplace, it should be connected by tubes with the chimney flue, the aperture being guarded by an Arnott's valve.

Fig. 87.



360. **Ventilating Gas-burners.**—As we before remarked, the common mismanagement of gas is a forcible illustration of the effect of ignorance or thoughtlessness, in often turning the best things to the worst account. Gaslight is cheap, brilliant and convenient, the very qualities we want; and so we turn it on and enjoy the flood of light. But bad air and headache supervene, and then gas-lighting is condemned, though the real fault is lack of ventilation. The use of gas-light greatly heightens the necessity for effective change of air; it generates poison exactly in proportion to its brilliancy. Dr. Faraday adopted the following successful plan to ventilate gas-burners

He placed a metallic tube about an inch in diameter over the lamp-glass, dipping down into it (Fig. 87) one or two inches, and connecting by its other extremity with a flue. But this was thought to be an ungraceful appendage to the chandelier, and has not come into use. He devised another, by which the tube carrying off the products of combustion, returned parallel with the supply pipe, but we have not seen it. There is report also of a still more elegant and successful English contrivance, but it cannot yet be found in this country.

361. **Ventilation of Cellars.**—It was seen that cellars are fountains of offensive air, which ascends through crevices in the floor, doors, windows, and stairways, often infecting the upper apartments with the noxious cellar atmosphere. If cellars are to be tolerated under our houses, they should be thoroughly ventilated. Perhaps the best plan is to extend a flue from the chimney down into the cellar, by which the fire-draught above shall constantly drain it. A tube or passage from the cellar to the top of the building, mounted with an ejecting cowl, answers a good purpose. Some go for abolishing cellars altogether.*

362. **Ventilation should be provided for in Building.**—There can be little question that the whole policy of warming and ventilating dwellings is yet in an unsettled and transition state, although this affords no apology for neglecting the subject. Much is known, and a great deal may be done about it to promote health and preserve life.

* "While I would condemn cellars and basements entirely, the common plan of building, in their absence, must be condemned also. The house being built above the surface of the earth, a space is left between the lower floor and the ground, which is even closer and darker than a cellar, and which becomes, on a smaller scale, the source of noxious emanations. Under-floor space should be abolished as well as cellars and basements. The plan that I have adopted with the most satisfactory success, to avoid all these evils, is the following: Let the house be built entirely above the ground; let the lower floor be built upon the surface of the earth, at least as high as the surrounding soil. If filled up with any clean material a few inches above the surrounding earth, it would be better. A proper foundation being prepared, make your first floor by a pavement of brick, laid in hydraulic cement, upon the surface of the ground. Let the same be extended into your walls, so as to cut off the walls of your house with water-proof cement, from all communication with the moisture of the surrounding earth. Upon this foundation build according to your fancy. Your lower floor will be perfectly dry—impenetrable to moisture and to vermin; not a single animal can get a lodgment in your lower story. By adopting this plan, your house will be dry and cleanly; the atmosphere of your ground floor will be fresh and pure; you will be entirely relieved from that steady drain upon life, which is produced by basements and cellars,—and if you appropriate the ground-floor to purposes of storerooms, kitchen, &c., you will find that the dry apartments thus constructed are infinitely superior to the old basements and cellars. And if you place your sitting and sleeping rooms on the second and third floors, you will be as thoroughly exempt from local miasma as Architecture can make you."—Dr. Buchanan.

Provision should be made for ventilation in the first construction of dwellings, as it may then be effectually and cheaply accomplished. The introduction of adequate arrangements, after the building is finished, is costly and difficult. The necessity is absolute for including ventilating provisions in houses as well as those for heat. Architects and Builders should make them a primary and essential element of their structural arrangements, and design in accordance with the principles of ventilation as an established art. It is to be regretted that too many in those professions to which a careless public commits its interests in this particular, are profoundly unconscious of the just claims of the subject, and totally unqualified to deal with it properly. This is hardly a matter of surprise when we recollect how recent it is that science has thrown its light upon the physiological relations of air. It is almost within the memory of men still living that oxygen gas was first *discovered*, and it is within twenty years that LIEBEG announced the last constant ingredient of the atmosphere (280). Architecture on the contrary rose to the dignity of a regular art thousands of years ago, when men had little more intelligent understanding of the real import of the breathing process than the inferior animals. We have therefore little cause for amazement when a book appears upon the subject of Architecture, of more than a thousand pages, and dispatches the whole matter of ventilation in ten lines—and that, too, with a sneer. Our buildings are hence commonly erected with less reference to healthful comfort than outside show, and ventilation is too much looked upon as a mere matter of tin tubes and knocking out bricks, that may be attended to at any time when it may be thought necessary.

363. **Ventilation involves necessary loss of Heat.**—The real practical difficulty in ventilation is its cost. Although the atmosphere is every one's property, and is the cheapest of all things, yet a supply of pure air in dwellings is by no means free of expense. To ensure ventilation we must have motion of air, and to produce motion demands force, which is a marketable commodity. Whatever will produce available force has value in it. Whether it be fans and pumps driven by steam-engines, or upward currents set in motion by naked fire, in both cases there is expenditure of fuel. It is true we may use the fire that must be kindled to produce warmth, and thus secure the additional result of ventilation, apparently without additional cost. But in most cases foul air is also warm air, and in escaping conveys away its heat, which is thus lost. Contrivances have been proposed, by which the outflowing warm air may be made to impart its heat to the incoming cold

air, but they are not yet reduced to practice. Until that is done, heat must continue to be lost by ventilation, just in proportion to its extent. Hence, as was before remarked, ventilation may be classed with food and apparel, and it becomes a question of how much can be afforded. But there is this important difference, that while economy in the latter—a plain table and coarse clothing—are at least equally favorable to health with more expensive styles of eating and dressing, economy of ventilation on the contrary, that is, any cheapening or deterioration of the vital medium of breathing, is injurious to health. One of the worst evils of scarce and expensive fuel is, that the poorer classes feel compelled to keep their rooms as tight as possible to prevent the escape of warm air and the consequent waste of heat.

PART FOURTH.

ALIMENT.

I.—SOURCE OF ALIMENTS—ORDER OF THE SUBJECT.

364. **View of the origin of Foods.**—The ground thus far traversed has furnished abundant illustration of the close alliance between man and the material universe, and of his subjection to physical influences; but we are now to see that he is composed of exactly the same materials as the solid globe upon which he dwells. Rocks, corroded by the agencies of time and crumbled into soils, join with the ethereal elements of the atmosphere, to furnish the substances of which the living body is composed. But rocks, soils, and air are not food. They are unorganized, lifeless matter; and can neither nourish the body, nor have they the power of uniting themselves together into nutritive compounds. The forces which play upon terrestrial atoms, throwing them into movement, arranging them into vital groups, and endowing them with the capability of becoming parts of animal systems, are shot down from the heavens. The impulses of organization and growth are not inherent powers of our earth, residing in air and soil. In the plan of the universe the SUN, a star among the stellar systems, is the architect of living forms, the builder of terrestrial organization, the grand fountain of vitality. His rays are streams of force, which, after travelling a hundred millions of miles through the amplitudes of space, take effect upon the chemical atoms of the earth's surface—its gases, waters, minerals, and combine them into nutritive, life-sustaining compounds. The vegetable world is the laboratory where this subtle chemistry is carried forward, and matter takes on the properties of organization. Such is the ultimate source of all our food. The solid materials which we perpetually incorporate into the bodily fabric, originated in plants, under the direct agency of the sun-

beam. The vegetable leaf is the crucible of vitality, the consecrated mechanism appointed to receive the life-forces which God is perpetually pouring through his universe. In partaking of the bounties of the table, are we not, then, consummating a purpose to which planetary systems are subservient? We repair the failing textures of animal life, but it is with tissues woven in a loom of invisible airs by the flying shuttles of light. That a single grain of wheat may be ripened—that its constituent starch, gluten and sugar may be perfected, this ponderous orb must shoot along the ecliptic at the rate of 68,000 miles per hour, from Taurus to Libra, whirling perpetually upon its axis as it flies, that all parts may receive alike the vitalizing radiations. When therefore we contemplate the grandeur of the operations by which the Creator accomplishes the problem of life in this state of being, the subject of foods rises to a transcendent interest. The consideration of these questions, however, the forces that control vegetable growth and give rise to organic compounds, pertains to chemistry and vegetable physiology; neither our plan nor our space will allow us to consider them here. We direct attention first to the general properties of foods, as we find them already produced and presented for preparation and use.

365. **How Foods may be considered.**—A systematic presentation of the subject of aliments, that shall be quite free from scientific objection, appears in the present state of knowledge to be impossible. We shall adopt an arrangement which aims only to be simple and popular. All articles of diet are composed of certain substances, which are known as *alimentary principles*,—*simple aliments*, and *proximate principles*. These are not the *ultimate* elements, carbon, oxygen, hydrogen, nitrogen, sulphur, &c., but are formed by combinations of these. They differ from each other in properties, exist in very different proportions in various kinds of food, and are capable of being separated from each other and examined independently. These require to be first considered. Next in order we shall speak of the products which these simple principles form when united together. Thus starch, sugar, gluten, &c., are *simple aliments;* while grain, roots, meats, &c., are made up of them, and are therefore called *compound aliments*. We shall give the composition of these, and as much of their history and preparation as may be necessary to understand their properties, and then trace the changes which they undergo in culinary management. The principles involved in various modes of preserving alimentary substances will next be described, and the subject closed by an examination of their physiological effects and nutritive powers.

366. **Division of Alimentary Principles.**—The simple alimentary principles are separated into two important divisions, based on their composition; *first*, the *non-nitrogenous* aliments, or those containing no nitrogen in their composition; and *second*, the *nitrogenous* aliments, or those which *do* contain this element. The first group consists of starch, sugar, gum, oil, and vegetable acids; while the second comprise albumen, fibrin, gluten, casein. Of these two classes the first is simpler in composition and much more abundant in nature than the other class; we shall hence consider them first. There is, however, another alimentary substance of peculiar properties, and of the first importance—*water*, which cannot be ranked strictly with either group. It is not a product of vegetable growth, but is rather a kind of universal medium or instrument of all sorts of organic changes. As the most abundant and indispensable of all the principles of diet, it claims our first attention.

II.—GENERAL PROPERTIES OF ALIMENTARY SUBSTANCES.

1. Principles Containing no Nitrogen.

A.—Water.

367. **Solvent Powers of Water.**—One of the most important properties of water is its wonderful power of dissolving many solids; that is, when placed within it they lose their solid form, disappear, and become diffused through the liquid. Such a combination is called *solution*. It is the result of a mutual attraction between the liquid and the solid, and it becomes weaker between the two substances as this attraction is satisfied. The action of water upon soluble substances is very powerful at first, but as solution proceeds the action gradually decreases, until the water will dissolve no more; it is then said to be *saturated*. Water saturated with one substance, may lose a portion ot its power to dissolve others, or its solvent energy may sometimes be increased; this depends upon the compound which it contains in solution. With some substances it combines in all proportions, and never gets saturated. Water does not dissolve *all* substances; if a fragment of glass and a piece of salt be put into it, the glass will be unchanged, while the salt will vanish and become liquid. Nor does it dissolve *alike* all that it acts upon; a pound of cold water will dissolve two pounds of sugar, while it will take up not over six ounces of common salt, two and a half of alum, and not more than eight grains of lime. Heat influences the solvent powers of water, most generally increasing it; thus, boiling water will dissolve 17 times as much saltpetre as ice

water. This it seems to do by repelling the particles of the solid body from each other, thus assisting the water to insinuate itself among them, by which its action is helped. But there are exceptions to the rule, of which lime is an example; sixty-six gallons of water at 32° dissolves one lb. of lime, but it takes 75 gallons at 60°, or 128 at 212°, to produce the same effect, so that ice-cold water dissolves twice as much lime as boiling water.

368. **How best to hasten Solution.**—Solids should be crushed or pulverized, to expose the largest surface to the action of the solvent liquid. Substances which in the lump would remain for days undissolved, when reduced to powder are liquefied in a short time. When a solid, as common salt or alum, is placed in a vessel of water to dissolve, it rests at the bottom. The water surrounding it becomes saturated, and being heavier, remains also at the bottom, so that the solution proceeds very slowly. By stirring, the action is hastened, but this takes up much time. The best plan is to suspend the salt in a colander, basket, or coarse bag, at the surface of the liquid. As the particles of water take up the particles of salt, they become heavier and sink; other particles take their places, dissolve more of the salt, and sink in turn, so that the action of a constant current of liquid is kept up on the suspended crystals, and always at that portion most capable of dissolving them.

369. **Solution of Gases—Soda-water.**—Water also dissolves or absorbs various gases, some more and some less. It may take 780 times its bulk of ammonia, an equal bulk of carbonic acid, or $\frac{1}{25}$ its bulk of oxygen. The quantity is, however, controlled by heat and pressure; heat acts to expel the gases, so that as the temperature rises, the water will hold less and less, while with increased pressure, on the contrary, it will receive an increased amount. Soda-water is thus by pressure overcharged with carbonic acid gas, which escapes with violent effervescence when the pressure is withdrawn. The effect is the same, whether the gas is forced into the water from without, or generated in a tight bottle or other vessel, as is the case with fermented liquors. The gas gradually produced is dissolved by the water, which, escaping when the cork is withdrawn or the vessel unclosed, produces the foaming and briskness of the liquor.

370. **Different varieties of Water.**—In nature water comes in contact with a great number of substances which it dissolves, so that there is consequently no perfectly pure, natural water. The substances which it takes up are numerous, and differ under various circumstances and conditions, and as these foreign substances or impurities which the

water acquires, communicate their properties to the liquid, it results that there are many varieties of natural water, as for example, spring-water, river-water, sea-water, rain-water, &c.

371. **Rain-water and Snow-water.**—Rain-water is the least contaminated of all natural waters, yet it is by no means perfectly pure. As it falls through the air, it absorbs oxygen, nitrogen, carbonic acid and ammonia, with which it comes in contact, and it also washes out of the atmosphere whatever impurities it may happen to contain. Thus, in the vicinity of the ocean, the air contains a trace of common salt; in the neighborhood of cities, various saline, organic, and gaseous impurities, while dust is raised from the ground and scattered through it by winds, and these are all rinsed out of the air by rains. The water which falls first after a period of drought, when contaminations have accumulated in the air for some time, is most impure. Rain falling in the country, away from houses, and at the close of protracted storms, is the purest water that nature provides. It differs from distilled water only in being *aërated*, that is, charged with the natural gases of the air. Falling near houses, it collects the smoky exhalations, and flowing over the roofs it carries down the deposited soot, dust, &c. Water from melted snow is purer than rain-water, as it descends through the air in a solid form, incapable of absorbing atmospheric gases. When melted, the water which it produces is insipid from their absence, and should be exposed for a day or two to the atmosphere, that it may absorb them.

372. **The Gases contained in Water.** There is an atmosphere diffused through all natural waters. It is richer in oxygen than is the upper atmosphere; in the latter there is but 23 per cent., while in the air of water there is 33 per cent. The animals which dwell in water absorb this oxygen by breathing, just as land animals do from the air, while water-plants in the same manner live on the carbonic acid it contains. These absorbed gases also influence its taste, giving it a brisk and agreeable flavor. If it is boiled they are driven off, and the liquid becomes flat and mawkish. The presence of as much oxygen as water will hold, improves it as a beverage, as this gas is necessary to the active performance of several of the most important vital functions. Water that is quite cold contains more oxygen than that which has been made warm in any way, as by exposure to the sun or the warmth of a close room, which causes a portion of it to escape.

373. **Organic Contaminations of Water.**—From the dust and insects of the air, the wash of the ground and the drainage of residences, from mud and decayed leaves, the decomposing bodies of dead ani-

mals, and a variety of other causes, waters are liable to contain *organic impurities*, or those vestiges of living structures which are capable of decomposition and putrefactive change. The effect of this organic matter may be shown by taking a little of the sediment that has accumulated at the bottom of a cistern, and placing it in a bottle of perfectly pure distilled water, when in a short time, if the weather be warm, it will begin to smell offensively. This kind of contamination may be either suspended mechanically in water as solid particles, or it may be dissolved in it so that the water shall still have an *appearance* of purity.

374. **The living Inhabitants of Water.**—Under certain favorable conditions of warmth, access of air, light, &c., countless numbers of living beings, both plants and animals, make their appearance in water. They are nourished upon the dead organic matter which the water may happen to contain, and belong either to the animal kingdom as *animalcula* or *infusoria*, or are of a vegetable nature, as *fungi*. There are other conditions which influence the *kind* of life which appears in water. If the liquid be slightly *alkaline*, animalcula will be produced, while if it be a little *acid*, fungi or microscopic plants will appear. This may be shown by diffusing a little white of egg through water in a wine glass, and keeping it in a warm place. If it be made in a small degree *alkaline*, it will swarm with animalcula in a few days; if, on the contrary, it be slightly acid, vegetable forms will be principally originated. It is important to notice also that the *alkaline* solution will run rapidly into putrefaction, and yield a putrescent smell, while the *acid* fluid will scarcely alter at all, and emit no unpleasant odor. It is hence obvious that these two kinds of water have different relations to human health, the slightly acid being more favorable to it than alkaline waters. These living inhabitants are never found in freshly fallen rain-water, caught at a distance from houses, nor in spring or well-water, but they more or less abound in cistern water, reservoir water, and marsh, pond, and river waters.

375. **Use of living beings in impure Water.**—The presence of living tribes in impure water, fulfils a wise and beneficent purpose. If the large amount of organic matter present in many waters could be removed only by the common process of putrefaction, and the formation of injurious compounds and offensive gases, immense mischief would be the consequence. To obviate this, nature has ordained that some of the organic matter of impure water, in place of undergoing decomposition, shall be imbibed by living beings, and these dying that others shall take their place and fulfil the same important office. The

Living races thus exert a preservative influence upon water, although this is more especially true of aquatic vegetation.

376. **Water dissolves variable quantities of Mineral Matter.**—Rain which falls upon high ground filters through the porous soil and strata of the earth until stopped by impenetrable clay or rock; it then passes along the surface of the bed until it finds an opening or crevice, through which it is forced up to the surface of the ground, producing a spring. Water which has thus leached through the mineral materials of the earth, dissolves such portions of its soluble materials as it meets with, and carries them down to the lower levels, so that they ultimately collect in the sea. The amount of mineral matter thus dissolved is extremely various. The water of the river Loka, in Northern Sweden, which flows over impervious, insoluble granite, contains only $\frac{1}{20}$ of a grain of mineral matter in a gallon weighing 70,000 grains. Common well-waters, spring-water and river-water, contain from 5 to 60 grains in a gallon, but generally, in waters of average purity, which are employed for domestic purposes, there are not present more than 20 or 30 grains of mineral matter to the gallon. When the dissolved substances accumulate until they can be tasted, a *mineral water* results. The celebrated Congress water, at Saratoga, contains 611 grains to the gallon. Ocean water has as much as 2,500 grains of saline substances, and the water of the Dead Sea the enormous quantity of 20,000 grains in the gallon. Of the two natural waters—those of the river Loka and the Dead Sea—the latter contains 400,000 times more saline matter than the former.

377. **Kinds of Mineral Matter dissolved by Water.**—The mineral substances dissolved in spring and well waters, are chiefly iron, soda, magnesia and lime, combined with carbonic and sulphuric acids, and forming *salts*, which are compounds of acids with alkalies or bases; sulphates and carbonates, together with chloride of sodium or common salt. Iron, mixed with carbonic and sulphuric acids, is present in most waters which percolate through the ground; soda and magnesia also often exist in these waters, but their most universal and important ingredient is lime. This exists in almost all soils in combination with carbonic acid as carbonate of lime, or powdered limestone, and it is also very common in the shape of sulphate of lime, or plaster. Most of these substances are soluble in pure water, but this is not the case with the widely diffused carbonate of lime. The power of dissolving this substance depends upon the presence of free carbonic acid contained within in the water. If charged with this gas, water becomes a solvent of limestone.

378. **Hard and Soft Water.**—The presence in water of these dissolved mineral substances, though in extremely small proportion, produces important changes in its properties. Compounds of lime and magnesia give it *hardness*, while rain and snow-water, and that from some springs which are free from these mineral matters, are called *soft*. This distinction of waters into hard and soft is usually connected with its cleansing qualities and its behavior towards soap, which we shall consider in another place. It is also important dietetically (533).

379. **Water in contact with Lead.**—There has been much contradiction among scientific men in regard to the effects of storing water in leaden vessels, or transmitting it through leaden pipes. It was known that some kinds of water would corrode or dissolve the lead and become poisonous; but *what* waters? Dr. CHRISTISON said those which were *soft*, while hard waters would form a crust in the interior surface of the lead, and thus protect it from corrosion. But later experimenters declare hard waters to be even worse than soft in their action upon lead. It may be remarked that water can act upon lead, corroding it without becoming itself actively poisonous, if the compound formed be *insoluble;* it is only when the lead is *dissolved* that the water containing it becomes dangerous. When ordinary water is placed in contact with lead, the free oxygen it contains combines with the metal, forming oxide of lead; water immediately unites with that producing hydrated oxide of lead, which is nearly insoluble in water. There is also more or less carbonic acid existing in all natural waters; this combines with the oxide of lead, forming *carbonate of lead*, which is also highly insoluble. But if there be in the water *much* carbonic acid, a *bicarbonate* of lead is formed, which is very soluble, and therefore remains dissolved in the water. Hence waters which abound in free carbonic acid, as also those which contain bicarbonates of lime, magnesia, and potash, are most liable to become poisoned by lead. Water containing common salt acts upon this metal, forming a soluble, poisonous chloride of lead. On the other hand, water containing sulphates and phosphates is but little injured, these salts exerting a protective influence on the lead. "From a review therefore of the whole of the arguments and experiments now advanced, respecting the action of different waters on lead, we deduce the following general conclusions: That while very soft water cannot be stored for a lengthened period, with impunity, in leaden vessels, the danger of the storage of hard water under the same circumstances is in most cases much greater. This danger, however, is to be estimated neither by the qualities of hardness or softness, but altogether depends upon

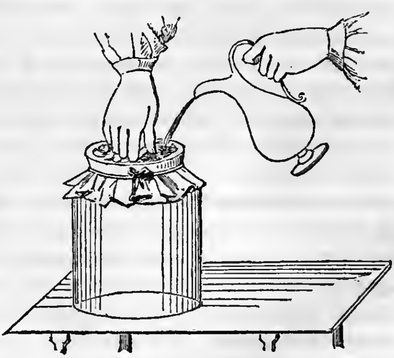
the chemical constitution of each different kind of water; thus, if this be ever so soft, and contain free carbonic acid, its action on lead will be great; whereas if it be hard from the presence of sulphates and phosphates principally, and contain but few bicarbonates, &c., little or no solution of the lead will result."—Dr. HASSALL. Water is powerfully corrosive of iron when conveyed through this metal in pipes, but the compounds formed are not injurious. *Galvanized* iron pipes, which have received a coating of tin (610), are coming much into use instead of lead for the conveyance of water.

380. **Supply of Soft Water.**—Wells and springs are often inacessible, or the water furnished is bad. In such cases the heavens furnish an unfailing resource, which, with well-constructed cisterns, filters, and ice, leave little to be desired in the way of aqueous luxury. Taking the annual rainfall at 36 inches, we have 3 cubic feet of water falling upon a square foot of surface in a year. A cubic foot contains $6\frac{1}{4}$ gallons, so that we get $18\frac{3}{4}$ gallons upon each surface foot annually. A house 25 by 40 has a thousand feet of surface, and collects nearly 19,000 gallons of water annually, which if stored in cisterns of sufficient capacity, will furnish more than 50 gallons per day throughout the year.

B.—The Starches.

381. **Whence obtained, and how separated.**—Starch, when pure, is seen to be a fine snow-white glistening powder. It is found universally distributed in the vegetable kingdom in much greater quantity than any other substance formed by plants for food. It exists in grain, peas and beans; in all kinds of seeds; in roots, as potatoes and carrots, and in the stem, pith, bark, and fruit of many plants. When wheat flour is mixed up into a dough, and washed (Fig. 88), on a linen cloth with clean water, a milky liquid passes through containing wheat starch, which gradually settles to the bottom of the vessel. If raw potatoes are

FIG. 88.



Separating Starch from flour by washing.

grated, and the pulp treated in a similar manner, potato starch is separated.

382. **Proportions in various substances.**—The variable proportion of starch in different articles of food is as follows, in decreasing order:

	Starch per cent.
Rice flour	84 to 85
Indian corn	77 to 80
Oatmeal	70 to 80
Wheat flour	89 to 77
Barley flour	67 to 70
Rye flour	50 to 61
Buckwheat	52
Pea and bean meal	42 to 43
Potatoes, containing 78 to 78 water,	13 to 15

383. **Starch Grains—their size.**—Starch consists of exceedingly small rounded grains. They cannot be distinctly seen with the naked eye, and are so extremely minute that the finest wheat flour, which has been ground to an impalpable dust, contains its starch grains mostly unbroken and perfect. The granules of potato starch are largest, while those of wheat and rice are much smaller (Fig. 89), and those of turnips and parsnips still smaller, varying all the way from

FIG. 89.

Starch-grains of potatoes. Starch-grains of plantain. Starch-grains of rice.

the 1-300th to 1-10,000th of an inch in diameter. Assuming the grains of wheat starch to be 1-1000th of an inch in diameter, a thousand million of them would be contained in a cubic inch of space.

384. **Their Appearance and Structure.**—Viewed under a high magnifier, starch grains from various sources exhibit marked peculiarities in form as well as in size. Several kinds have a ringed or grooved aspect, as seen in Fig. 89, which appearance is explained by the fact that they consist of concentric layers or membranes, like the coats

of an onion. The grains of potato starch are ovoid or egg-shaped. Many of the grains of pea starch are hollowed or concave in the direction of their length, while wheat starch consists of dull, flattened, lens-shaped grains, sticking together when not perfectly dry, on which account the wheat starch of commerce always comes in loose lumps. Thus each variety of starch-grain has some peculiar appearance of its own, by which the practical microscopist is enabled to identify it. He can hence detect adulterations of the more valuable with the cheaper varieties, as wheaten flour or maranta arrow-root with potato starch.

385. **Sago Starch** is procured from the pith of several varieties of the palm tree. It comes in various forms. Sago meal or flour is a whitish powder. *Pearl-sago*, the kind in general use for domestic purposes, consists of small pinkish or yellowish grains, about the size of a pin's head. Common or brown sago consists of much larger grains, which are of a brownish white color, each grain being brownish on one side and whitish on the other. As all the kinds of sago contain coloring matters, they are considered inferior to those varieties of starch, as arrow-root and tapioca, which are perfectly white.

386. **Tapioca** is a variety of starch which comes from South America, and is obtained from the root of a plant containing a poisonous milky juice. When it appears as a white powder, it is called *Brazilian arrow-root.* The term *tapioca* is commonly applied to that form of it which appears in small irregular lumps, caused by its having been dried on hot plates, and then broken up into fragments.

387. **Arrow-root.**—A root growing in the West Indies (the *Maranta arundinacea*), contained a juice supposed to be capable of counteracting the effects of wounds inflicted by poisonous arrows. This root yielded a starch which took the name of *maranta arrow-root.* But afterward starches from other plants which had a resemblance to maranta starch, took also the name of arrow-roots. Thus there is *Tahiti* arrow-root, *Manihot* arrow-root, from the plant which yields tapioca, and potato arrow-root, or British arrow-root, as it is sometimes called. Maranta arrow-root, which is a very pure white starchy powder, is the most prized of all the varieties, but it is often adulterated with other and cheaper kinds.

388. **Corn Starch.**—This is a preparation of the starch of Indian corn, which has been separated as perfectly as possible from the other constituents of the grain. Chemical means are used to effect the separation. The starch is freed from the glutinous, oily and ligneous elements of the seed, by the aid of alkaline solutions, and by grinding

and bolting the corn in a wet condition. The grain is reported to yield from 30 to 35 per cent. of pure starch, which bears a general price, about one-third greater than wheaten flour. The culinary changes of starch and its effects upon the system will be considered under these topics (516).

389. **Chemical Composition.**—Starch consists of three elements,—carbon or charcoal, oxygen, and hydrogen. The two latter are found in starch in exactly the same proportions that they exist in water, so that the composition of this substance may be given as simply charcoal and water. A compound atom of starch consists of twelve atoms of carbon, combined with ten of oxygen and ten of hydrogen, or twelve atoms of carbon to ten of water.

C.—The Sugars.

390. **Proportion in various Substances.**—This is the sweet principle of food, and is produced by both plants and animals. It exists in milk, and it has lately been shown that it is generated in the animal liver. But our supplies come entirely from the vegetable world, where it is produced in great abundance, both in the sap and juices of plants, and stored up in their fruits and seeds. The following is the proportion of sugar obtainable from various sources:

	Per cent. of Sugar.
Juice of Sugar cane	12 to 18
Beet root	5 to 9
Wheat flour	4 to 8
Barley meal	5·2
Oat meal	4·8
Cow's milk	3·3
Rye meal	3·2
Peas	2
Indian corn	1·5
Rice	·2

There are several varieties of sugar, but we are practically concerned with but two, cane sugar and grape sugar.

391. **Grape Sugar or Fruit Sugar.**—The white sweet grains of raisins or dried grapes take the name of *grape sugar*. Most other fruits, however, as apples, pears, plums, figs, cherries, peaches, gooseberries, currants, &c., grow sweet in ripening, which is owing to the same kind of sugar which exists in the grape. It may be readily extracted from fruits, but this is rarely done.

392. **Sugar Artificially Produced.**—If starch be boiled for some time in water which has been soured by adding to it one or two per cent. of sulphuric acid, the solution gradually acquires a sweet taste. If,

now, by suitable means, the acid be neutralized and removed, and the solution boiled down, it yields a rich sirup or a solid sugar. This comes from the transformation of starch; the acid taking no direct part in the change, but only inducing it by its presence. Potatoes treated in this way, it is said, will produce ten per cent. of their weight of sugar. But what is still more singular, the fibre of wood may also be converted into sugar. Paper, raw cotton, flax, linen and cotton rags, and even sawdust, may be changed to sugar by the same agency. The boiling with acid must, however, in this case, be continued longer, as the woody matter has first to be changed to starch before it becomes sugar. This product, known as *starch sugar*, has the same nature and properties as grape sugar.

393. **Honey.**—This is obtained by bees from the juices found in the nectaries, or honey-cups of flowers. They collect it in the crop, or honey-bag, which is an enlargement of the gullet, and when filled is about the size of a pea. Laden with its sweet treasure, the insect returns to the hive and disgorges it into a previously prepared cell of the honeycomb, which it then caps over by a thin covering of wax. To procure it in the purest liquid form, and of the best flavor, the plan is to unseal the cells by removing a slice from the surface of the comb, after which it is laid upon a cullender to drain. It is sometimes warmed, to facilitate the flowing, but this is said to injure the delicacy of its flavor. It is more commonly pressed. This increases the quantity, and saves time; but it is then contaminated by traces of wax, and fouled by the juices of crushed bee-maggots, which may happen to be in the comb.

394. **Properties and Composition.**—Honey, in different localities, different seasons, and from different flowers, varies very much in color, flavor, and fragrance. That from clover, or from highly fragrant flowers, is far superior to that from buckwheat; spring-made honey is better than that produced in autumn. *Virgin* honey, or that made from bees that never swarmed, is finer than that yielded by older swarms; and while some regions are renowned for the exquisite and unrivalled flavor of their honeys, that made in some other places is actually poisonous. We can hardly suppose honey to be a simple vegetable liquid. It probably undergoes some change in the body of the insect by the action of the juices of the mouth and crop, as when bees are fed upon common sugar alone they produce honey. Honey is an intensely sweet sirup, varying in color from nearly white to a yellowish brown. It consists of two sorts of sugar. One of these remains always in a liquid or sirupy condition, and the other is liable to crystallize or

change to solid grains (*granulate*), this is grape sugar. The lightest colored and most valuable honeys contain the most of it, and hence are most liable to granulate and grow thick. Honey contains an acid, and aromatic principles, which together with its uncrystallizable sweet part, are not very well understood.

395. **Cane Sugar—its Sources.**—Our common sugar is obtained, as is well known, from the sugar-cane. Eleven-twelfths of all the sugar of commerce has this origin. That which is procured from the ascending sap of the maple, the descending sap of the birch, and also from the walnut and other trees; from the juice of beets, carrots, turnips and melons, from green corn-stalks, and the unripe seeds of grain, is identical in essential properties with that of the sugar-cane, and they are all distinguished as *cane sugar*.

396. **Cane and Grape Sugars, different conditions of origin.**—It is necessary to understand clearly the difference between cane sugar and grape sugar. We have seen that the agency of acids is employed to convert starch into grape sugar, and they have the same effect upon cane sugar. This change takes place even in the interior of growing plants. Those plants and fruits which possess sour or acid juices, yield grape sugar, while those which contain little or no acid in their saps, contain generally cane sugar. Grape sugar may be produced by art, while cane sugar cannot.

397. **Cane and Grape Sugars, chemical differences.**—Sugar, like starch, consists only of carbon and water; but these two sugars differ in the proportion of these elements. While cane sugar contains twelve atoms of carbon to eleven of water, grape sugar contains twelve atoms of carbon to fourteen of water. Grape sugar is therefore less rich in carbon than cane sugar, and cane sugar may be transformed into grape sugar by the addition of chemically combined water. It is an essential property of sugar, that under the action of ferments, they are decomposed; converted into carbonic acid and alcohol. Grape sugar is most prone to this change; and cane sugar, before it can undergo fermentation, must be first changed into grape sugar. Cane sugar passes into the solid state much more readily than grape sugar, taking on the form of clear, well defined crystals of a constant figure; grape sugar, on the contrary, crystallizes reluctantly and imperfectly, without constancy or form. Crystals of cane sugar are regular six-sided figures, while those of grape sngar are ill-defined, needle-shaped tufts.

398. **Difference of solubility and sweetening powers.**—Pure cane sugar remains perfectly dry and unchanged in the air, while grape sugar

attracts atmospheric moisture, becoming mealy and damp. Yet cane sugar dissolves in water much more readily than grape sugar. While a pound of cold water will dissolve three pounds of the former, it will take up but two-thirds of a pound of the latter. Cane sugar will, therefore, make a much thicker and stronger sirup than grape sugar, dissolving also more freely in the juices of the mouth, (a property upon which *taste* depends). Cane sugar possesses a higher sweetening power than the other variety. Powdered grape sugar has a floury taste when placed upon the tongue, and very gradually becomes sweet and gummy or mucilaginous as it dissolves. Two parts by weight of cane sugar are considered to go as far in sweetening as five of grape sugar. To make them economically equal, therefore, five pounds of grape sugar should cost only as much as two of cane sugar; and hence the mingling of grape with cane sugar is a serious deterioration of it.

399. **How Raw, or Brown Sugar is produced.**—The sugar of commerce appears in various forms, and is sold at various prices. It is important to inquire into the source of these differences which involves a reference to the manufacture. Cane-juice contains vegetable albumen, a substance which has a strong tendency to fermentation (488), hence, when left to itself in warm climates, it is rapidly changed; the acid of vinegar being generated;—twenty minutes is, in many cases, sufficient to produce this effect. To neutralize any acid that may be thus formed, and partially to clarify the crude juice, lime, which has a powerful attraction for organic matter, is added. The juice is then boiled, the water being evaporated away until a sirup is produced. The liquid is then drawn off into shallow vessels and stirred. As it cools the sugar *granulates*, or appears in the form of small irregular *grains* or crystals, which are kept from uniting together by some of the sirup (which has been so altered by the heat that it refuses to crystallize), and is known as *molasses*. The product is then placed in suitable circumstances to drain, when a large portion of the molasses flows away, and is collected in separate vessels. The sugar, packed in hogsheads, is then sent to the market as raw or muscovado, or as it is more commonly known, as *brown* sugar.

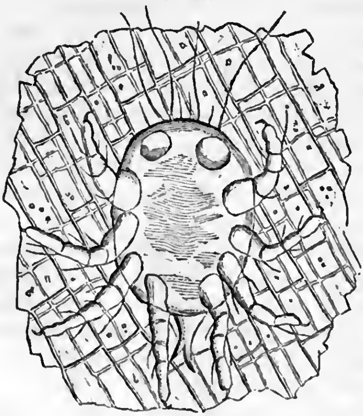
400. **Of what Brown Sugar consists.**—The article when packed by the sugar-boiler, consists of sugar more or less browned and dampened by molasses, according to the completeness of the draining and drying process. It contains more or less vegetable albumen, lime from the added lime-water, minute fragments of crushed cane-stalks, often in considerable quantity, with grit or sand from the unwashed canes,

or which may have been introduced into the granulating vessels by careless management.

401. **Brown Sugar undergoes a slow fermentation.**—We have stated that albumen is a very changeable substance, and by its own decomposition, when in contact with sugar, tends to alter *that* also. Cane sugar, it transforms into grape sugar. Hence, in nearly all raw sugars, there is an incipient, slow fermentation going forward, by which a portion of cane sugar is converted into grape sugar. Dr. HASSALL, perhaps the highest authority in matters pertaining to alimentary impurities, states that nearly all samples of brown sugar contain also grape sugar, and that its proportion is greater where there is most vegetable albumen. This change, of course, just according to its extent, lowers the value of brown sugar.

402. **Living contaminations of Brown Sugar.**—We had occasion, when speaking of water, to correct that common impression of the ill-informed, that swarms of animalculæ are present in every thing we eat and drink. On the contrary, they exist only in certain circumstances, and when they do occur, of course impair the value of food for dietetical use. As all animal structures, from the largest to the smallest contain nitrogen, one of the conditions of the existence of animalculæ is the presence of nitrogeneous matter upon which to feed. Now pure sugar contains no nitrogen, and therefore cannot sustain animal life. But in brown, coarse sugars the existence of vegetable albumen offers nourishment to these beings, and accordingly they are commonly found infested with minute insects called *sugar-mites*. In general, the more the sugar is contaminated with albumen, the more numerous are these disgusting insects. They may be detected in the less pure sugars by dissolving two or three tea-spoonfuls in a large wine-glass of tepid water. After standing at rest an hour or two, the animalculæ will be found, some on the surface of the liquid, some adhering to the sides of the glass, and some in the dark sediment at

FIG. 90.



Sugar-mite, as seen upon a fragment of cane, magnified 130 diameters.

the bottom, mixed with cane-fragments, grit, and dirt. The mite is visible to the naked eye, as a mere speck; the microscope, however, exhibits its appearance, and history, from the egg state to the perfectly developed animal, which is represented in Fig. 90.

403. **Properties and Composition of Molasses.**—Common molasses is a dense brown liquid, the drainage of the brown sugar manufacture. It contains a portion of sugar that has been burnt and darkened in boiling; another part that has been so changed to the mucilaginous state, by boiling, that it does not crystallize, together with a quantity of crystallizable sugar. It is strongly absorbent of water; indeed, many kinds of raw sugar melt into sirup when exposed to the air. Chemically considered sugar is an acid substance, and combines with bases, as potash, soda, magnesia, to form salts called *saccharates*. Molasses contains a portion of saccharine matter, combined with the lime used in the sugar manufacture (399); also with small quantities of the alkalies. Molasses itself is also acidulous. It has a peculiar strong taste, which CADET states may be removed by boiling for half an hour with pulverized charcoal. *Sugar-house molasses* and sirups are the residue which remains uncrystallized in purifying and refining brown sugar.

404. **Refined Sugar.**—To cleanse it of impurities and improve it in color and taste, crude sugar is *refined*. It is melted and has mingled with it a small portion of albumen (ox-blood), which clears it of mechanical contaminations. The sirup is then filtered through a bed of animal charcoal (burnt bones crushed), by which it is decolorized, and lastly, it is crystallized, by boiling at a low temperature in vacuum-pans, in which the atmospheric pressure is removed (62). The discoloring and darkening principle in the various grades of sugar is the molasses which has not been removed, but which remains in the crystallized mass.

405. **Sugar-candy and how it is Colored.**—When the pure sugar is melted or dissolved, it forms a clear liquid, and when allowed to cool or dry without disturbance, it crystallizes into a transparent solid, like glass. When threads are suspended in the sugar solution, crystals of extreme hardness collect upon them, which are known as *rock-candy*. The cause of *whiteness* in refined sugar is that the crystals are small, confused, and irregular. To make candy white, the sugar, while cooling, is agitated and worked (*pulled*), which breaks up the crystals and renders the mass opaque. Candy is commonly adulterated with flour, and frequently with chalk. Various colors are given to sugar-confectionery by adding paints and dies expressly for the purpose. Some of these are harmless and others poisonous. Those which are least inju-

rious are the vegetable and animal coloring matters, but these neither form so brilliant colors nor are they so lasting as the mineral compounds, which are far the most deadly. The following are the chief coloring substances used by confectioners to beautify their sugar preparations:

REDS	Oxide of lead (*red lead*). Bisulphuret of mercury (*vermilion*). Bisulphuret of arsenic (*red orpiment*).
YELLOWS	Gamboge. Chromate of lead (*chrome yellow*). Sulphuret of arsenic (*yellow orpiment*).
BLUES	Ferrocyanide of iron (*Prussian blue*). Cobalt. Smalt (*glass of cobalt*). Carbonate of copper (*verditer*). Ultramarine.
GREENS	Diacetate of copper (*verdigris*). Arsenite of copper (*emerald green* . Carbonate of copper (*mineral green*).
WHITES	Carbonate of lead (*white lead*).
PURPLES	Formed by combining blues and reds.

From an examination of 101 samples of London confectionery, Dr. HASSALL found that 59 samples of *yellow* were colored with *chromate of lead* and 11 with *gamboge*. That of the reds 61 were colored with *cochineal*, 12 with *red lead*, and 6 with *vermilion*. Of the blues, one sample was colored by indigo, 22 by *Prussian blue*, and 15 by *ultramarine*. Of the greens 10 were colored by a mixture of *chromate of lead* and *Prussian blue*, 1 with *carbonate of copper*, and 9 with *arsenite of copper*. These colors were variously combined in the different cases, as many as from three to seven colors occurring in the same parcel, including three or four poisons.

406. **Their dangerous and fatal Effects.**—The Dr. remarks: "It may be alleged by some that these substances are employed in quantities too inconsiderable to prove injurious, but this is certainly not so, for the quantity used, as is amply indicated in many cases by the eye alone, is often very large, and sufficient, as is proved by numberless recorded and continually recurring instances, to occasion disease and death. It should be remembered, too, that these preparations of lead, mercury, copper, and arsenic, are what are termed *cumulative*, that is, they are liable to accumulate in the system, little by little, until at length the full effect of the poisons become manifested. Injurious consequences have been known to result from merely moistening wafers with the tongue; now the ingredients used for coloring these include

many that are employed in sugar confectionery. How much more injurious, then, must the consumption of sugar thus painted prove when these pigments are actually received into the stomach."

D.—The Gums.

407. **Properties of the Gums.**—The juices of many plants contain substances which ooze out through the bark, forming rounded transparent masses of *gum*, as we often see upon cherry, plum, peach and apple trees. The gums differ considerably in properties. Cherry-tree gum is insoluble in cold water, but dissolves readily in boiling water, while gum-arabic dissolves in cold water, and gum-tragacanth dissolves in neither, but only swells up into a kind of *mucilage*. The solutions of gums are clear and tasteless, and have a glutinous and sticky nature, which adapts them for paste.

408. **Artificial Gum.**—When common starch is heated to 300 degrees in an oven, or boiled in water made sour by a little sulphuric acid, it is so altered as to dissolve in cold water, forming a clear, viscid solution. The substance thus produced from the starch has the properties of gum, and is known as *dextrine*.

409. **How Gum is Composed.**—In chemical composition, gum and dextrine do not differ from starch; they consist of 12 atoms of carbon combined with 10 of water. Gum exists in grains, and many vegetables, and hence is a widely-diffused element of food, although it does not occur in large quantities. Its dietetical value, as shown by its composition, is the same as starch and sugar, and hence it is grouped with the saccharine alimentary principle.

E.—The Oils.

410. **Distinction between Volatile and Fixed Oils.**—Oils are of two classes: 1st, those which, when smeared upon paper, produce a stain or grease spot, which does not disappear by time or warmth, and hence called *fixed* oils; and, 2d, such as will vanish from paper, under such circumstances leaving no permanent stain, and therefore called *volatile* oils. The former is a universal and important element of diet, the latter presents itself chiefly among condiments, and will be there considered.

411. **Sources and Forms of Oily Bodies.**—Oil is largely procured both from plants and animals, and from both sources it is chemically the same thing. It exists in many parts of vegetables, but is chiefly stored up in their seeds, from many of which it is obtained by pressure

in large quantities. In animal bodies it is deposited in the sacks or cavities of cellular tissue, and becomes accumulated in large quantities in different parts of the body. Oils and fats are chemically identical, differing only in *consistence*, and this quality depends upon temperature. Lowering the temperature of a liquid oil sufficiently, changes it to a solid, while raising that of a solid tallow converts it into a flowing oil. That which, in the hot climate of Africa, is *liquid palm oil*, is with us solid *palm butter*. Those oils, however, which at ordinary temperatures are not perfectly fluid, but have what is called an oily consistence, become much thinner and completely liquid when heated.

412. **Proportion of Oil in Articles of Diet.**—The proportion of oily matter from many sources is variable, as in the case of meat, which may more or less abound in fat. Nor has its amount in many vegetables been determined with sufficient certainty. The following are the quantities given by the later authorities:

Yolk of Egg	28·75	per cent.
Ordinary Meat (Liebig)	14·03	"
Indian Corn	9·	"
Oatmeal (husk excluded)	6·	"
Cow's Milk	3·13	"
Rye Flour	3·5	"
Wheat Flour	1 to 2	"
Barley Meal	2·	"
Potatoes (dried)	1·	"
Rice	·8	"
Buckwheat	·4	"

413. **Its Composition.**—Oleaginous bodies are distinguished from all the other alimentary principles, by their chemical composition, and the resulting properties. They resemble the preceding substances which we have been considering in containing three elements, carbon, hydrogen and oxygen; but they differ from all of them in this important respect, that they are composed almost entirely of hydrogen and carbon, with but a small proportion of oxygen. The composition of hogs-lard, as given by Chevreul, may be taken as an example of the general structure of this alimentary group. It consists of carbon 79, hydrogen 11, oxygen 10 parts in a hundred. We have seen that hydrogen and carbon are the active fire-producing elements of fuel (80). As the oils are so rich in these, they rank high as combustibles, burning with great intensity, and yielding much heat. It has been also noticed that oils may be decomposed into several acid and basic principles (195).

F.—The Vegetable Acids.

414. **Combination and Composition.**—The sourness of fruits and succulent vegetables is due to various acids produced in the plant, and which they contain usually in quite small proportions. They exist in two states: 1st, as pure acids, or free, when they are strongest; and, 2d, combined with bases, as potash, lime, &c., by which they are partially neutralized, and thus rendered less pungent to the taste. In this case they exist as acid salts (691). The vegetable acid group consists of but three elements, carbon, oxygen, and hydrogen, like the starch and oil groups, but it is distinguishable from them by containing but a small share of hydrogen and a large proportion of oxygen. The composition of the different vegetable acids is quite variable, but they all agree in possessing less hydrogen and more oxygen than any other class of organic alimentary principles. Their nutritive value is very low.

415. **Acid of Apples—Malic-Acid.**—This is the peculiar acid of apples, and it is also found in numerous other fruits. Thus, it exists free in pears, quinces, plums, peaches, cherries, gooseberries, currants, strawberries, raspberries, blackberries, elderberries, pineapples, grapes, tomatoes, and several other fruits. It exists very abundantly in green apples, causing their extreme acidity, and diminishes as they ripen. The wild crab-apple is much richer in malic-acid than the cultivated fruit, and generally speaking, in proportion as we obtain sweetness by culture, we deprive the apple of its *malic-acid.* No use is made of this acid in the separate state.

416. **Acid of Lemons—Citric-Acid**—Gives their sourness to the lemon, orange, citron, and cranberry. Mixed with malic-acid, it exists also in the gooseberry, red-currant, strawberry, raspberry, and cherry. Citric-acid is separated from lemon juice, and sold in the form of crystals, which may be at any time redissolved in water, and by flavoring with a little essence of lemon, an *artificial lemon juice* is produced, which is used like the natural juice in the preparation of refreshing and cooling beverages.

417. **Acid of Grapes—Tartaric-Acid.**—This acid in the free state exists in the grape, and is found besides in some other fruits. It also exists abundantly in the grape in combination with potash, as acid, tartrate of potash, or cream-of-tartar. Tartaric-acid is prepared and sold in the crystalline form as a cheap substitute for citric-acid, or lemon juice. It does not absorb moisture when exposed to the air like citric-acid, but is inferior to it in flavor. The commercial effer-

vescing, or *soda powders*, consist of 30 grains of bicarbonate of soda, contained in a blue paper, and 25 grains of tartaric acid, in a white paper, to be dissolved in half a pint of water.

418. **Oxalic-Acid**—Exists in sorrel, and also in the garden rhubarb or pie-plant, combined with and partially neutralized by potash or lime. It is a prompt and mortal poison when pure, and fatal results frequently occur from mistaking its crystals for those of Epsom salts, which they much resemble.

419. **Vegetable Jelly, Pectine or Pectic-Acid.**—This is obtained from the juice of apples, pears, quinces, currants, raspberries, and many other fruits; also, from turnips, carrots, beets, and other roots. It is composed similarly to the vegetable acids, having an excess of oxygen. Vegetable jelly is thought not to exist exactly *as such* in the plant-juices, but to be produced from another substance in the process of its separation. The substance from which it is obtained is soluble in the vegetable juices, but the jelly itself is scarcely soluble in cold water. Boiling water dissolves it, but it coagulates again as the water cools. It is commonly prepared by mixing sugar with the juice, and suffering it to stand for some time in the sun, by which a portion of the water is evaporated; or it may be boiled a short time. But when long boiled, it loses the property of gelatinizing by cooling, and becomes of a mucilaginous or gummy nature. This is the reason that in making currant or any other vegetable jelly, when the quantity of sugar is not sufficient to absorb all the water, and consequently it becomes necessary to concentrate the liquor by long boiling, the mixture often loses its peculiar gelatinous properties, and the jelly is of course spoiled. It differs from animal jelly in containing no nitrogen, and although readily digestible, it is supposed to be but slightly nutritive. Isinglass is often added to promote the stiffening of vegetable jellies, and sugar also has a similar effect. They form cooling and agreeable articles of diet for those sick with fevers and inflammatory complaints. *Jams* consist of vegetable pulps preserved with sugar. They are very similar in their uses and effects to the fruit-jellies, from which they principally differ in containing a quantity of insoluble, and therefore indigestible ligneous matter (or vegetable membranes, cellular-tissue and sometimes seeds), which in the healthy state of the system contribute by their mechanical stimulus to promote the action of the bowels, but in irritable conditions of the alimentary canal, sometimes prove injurious.—(PEREIRA.)

420. **Acetic Acid, or Vinegar.**—The acid in most general use for dietetical purposes is the acetic, or acid of vinegar, which we obtain b

fermentation (491). Good strong vinegar contains about four per cent. of the pure acid. Vinegar may be easily made at any time by adding ferment, or yeast, to water sweetened with sugar or molasses, or any sweet vegetable juice, and exposing the whole for a reasonable time to the air in a warm place. Vinegar itself added to the mixture will act in the way of yeast to start the operation. There accumulates in old vinegar a thick, ropy matter, called *mother*, because it is capable of producing the acetous change in a sugary solution. It consists, like yeast, of vegetable cells (496). The juices of most fruits contain all the elements necessary for fermentation and souring. Apple and grape juice, at first, undergo the vinous change producing cider and wine, and the process continued converts them both into vinegar (*cider-vinegar* and *wine-vinegar*), which are prized, on account of the fruity aroma which accompanies them.

2.—Principles Containing Nitrogen.

A.—Vegetable and Animal Albumen.

421. **It exists in both organized Kingdoms.**—We are all familiar with albumen or white of eggs, and recollect the remarkable change it undergoes by heat, being coagulated or altered from a transparent liquid to an opaque, white, brittle solid. This substance exists in small proportions dissolved in the juices of plants. If such juices are clarified and then boiled, the albumen coagulates in thin flakes, and may be separated from the liquid. The same substance exists also in small quantities, laid up dry and solid in seeds and grains, but its exact proportion in various parts of plants has not been ascertained. Albumen exists also in animals, and is a much more abundant constituent of these than of plants. It constitutes, according to Regnault, about 19 per cent. of healthy human blood, and is therefore found in large quantities in all parts of the system. It exists in the peculiar animal juices, in the glands, nerves, brain, and around the muscular fibres of flesh.

422. **Composition of Albumen.**—In composition, albumen differs widely from the aliments we have considered; it contains not only the aliments they contain—carbon, oxygen, and hydrogen,—but in addition, a large proportion of nitrogen, and also a minute amount of sulphur. The chemical structure is thus complex. The result of the latest analysis is, that a compound atom of albumen consists of 216 carbon, 189 of hydrogen, 68 of oxygen, 27 of nitrogen, and 2 of sulphur. The albumen of eggs, however, contains a slightly larger proportion

of sulphur. Vegetable and animal albumen are essentially the same thing in properties and composition, differing no more upon analysis than two samples from the same source.

423. **General Properties of Albumen.**—It exists in two states—soluble and insoluble, or coagulated. The coagulation is effected by simple heat; but there is much confusion of statement among different writers as to the point of temperature at which it solidifies. This depends upon circumstances. A moderately strong solution of pure albumen in water becomes turbid at 140°, and completely insoluble at 145°, and separates in flakes at 167°. When excessively diluted, no turbidity can be produced by a less heat than 194°, and it will only separate in solid masses after it has been boiled a considerable time. As a general rule, albumen coagulates with greater difficulty in proportion to the quantity of water in which it is dissolved. Coagulated albumen refuses to dissolve in cold water, merely swelling up in it. There are many substances which, if mixed with it, coagulate albumen when cold, as alcohol and corrosive sublimate, the mineral acids, and many salts, while the presence of alkalies hinders its coagulation. The change of coagulation does not alter or disturb its composition.

B.—Vegetable and Animal Casein.

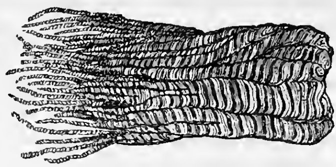
424. **Source and Composition.**—The water in which flour has been washed or diffused, as in separating starch, contains a small portion of a dissolved substance, which is coagulated by the addition of an acid, and may be then separated. It is called *vegetable casein*, and is found in the largest proportion in peas and beans, constituting from 20 to 28 per cent. of their weight. This substance is identical in properties with the curd of milk, which is known as animal casein, and is the chief ingredient of cheese. The identity of vegetable and animal casein is well illustrated by the fact that the Chinese make a real cheese from peas. They are boiled to a thin paste, passed through a sieve, and coagulated by a solution of gypsum. The curd is treated like that formed in milk by rennet. The solid part is pressed out, salted, and wrought into cheese in moulds. This cheese gradually acquires the smell and taste of milk cheese; and when fresh, is a favorite article of food with the people. The composition of vegetable and animal casein is nearly if not quite identical with that of albumen (422).

C.—Vegetable and Animal Fibrin.

425. **The Blood and Vegetable Juices.**—When blood is drawn from

the living body, in a short time it *clots;* that is, a net-work of fibres is formed within it. These fibres consist of *animal fibrin*, which was dissolved in the blood, and then took on the solid form (*spontaneous coagulation*). Vegetable juices, as those expressed from turnips, carrots, beets, &c., also contain the same kind of matter which they deposit on standing, that is, it *spontaneously coagulates*, and this is known as vegetable fibrin. If a piece of lean beef be long washed in clean water, its red color, which is due to blood, gradually disappears, and a mass of white fibrous tissue remains, which is known as animal fibrin. The accompanying diagram (Fig. 91) shows its structure as seen under the microscope. The parallel fibres have cross markings, wrinkles, or striæ. By the contraction of a muscle in the living animal the striæ are made to approach each other, become less distinct, and the fibre increases considerably in breadth and thickness.

FIG. 91.



Fibres of lean meat magnified.

426. **Gluten.**—If wheat flour be made into a dough, and then kneaded on a sieve or piece of muslin under a stream of water (Fig. 92), its starch is washed away, and there remains a gray, elastic, tough substance, almost resembling a piece of animal skin in appearance. When dried it has a glue-like aspect, and hence its name, *gluten*. When thus produced, it consists chiefly of vegetable fibrin; but it contains also a little oil, with albumen and casein. That from other grains is different in the proportion of these constituents; rye gluten, for example, consists largely of casein, and has less of the tenacious fibrinous principle. By acting upon crude gluten with different solvent agents, it is separated into four principles as follows:

FIG. 92.

Vegetable fibrin	72	per cent.
Gluten	20	"
Casein (mucine)	4	"
Oil	3·7	"
Starch (accidental), small quantity		
Total	99·7	"

427. **Animal Fibrin.**—The muscles or lean meat of animals are principally composed of this substance, its proportionate quantity being greatest in flesh that is dark-colored, and belongs to animals that have attained their full growth. Its characters vary somewhat in different animals, and in the same animal at different ages. Its color is variable; in beef and mutton it is red; in pigeons and many kinds of game it is brownish; pink in veal, salmon color in pork; in fish, white or semi-transparent, though all animals yield it on various colors. When washed free from blood and other foreign substances, pure fibrin is white and opaque, but darkens by drying.

428. **Properties of the Nitrogenous Principles.**—Whatever their form or source, these substances are identical in composition, a fact of great importance in connection with animal nutrition. They present variations of aspect and physical properties, and different solubilities, albumen and casein being soluble in water, while the others are not; and while fibrin coagulates or solidifies spontaneously, albumen is altered in the same manner by heat, and casein by acids. It is possible that some of these conditions may be influenced by the mineral phosphates which these substances contain in variable amount, but this point is not yet determined. These substances are decomposed by heat, and exhale a pungent odor like that of burnt feathers. They may be long preserved when dried, or even in the moist state when cut off from the atmosphere; but in contact with air and moisture they quickly decompose, putrefy, and call into existence a host of microscopic animalculæ. We shall consider these substances again (678).

D.—Gelatin.

429. **Its Sources, Properties and Uses.**—There exists in the bone, cartilages and various membranes of animal bodies, a principle rich in nitrogen, called *gelatin*. It is not identical in composition with the nitrogenous class which we have been considering, nor is it like them produced in the vegetable kingdom; but it is supposed to be derived *from* them in the animal system. It dissolves in hot water, and when cooled, forms a white jelly. It is the universal principle of animal jellies. Common glue consists of gelatin, but in this form it is not

used dietetically. *Isinglass* is a preparation of gelatin in various forms to be used as food. It is mainly procured from the air-bag or bladder of fishes. Four parts of isinglass convert 100 of water into a trembling jelly. Gelatin is also extracted from calves' feet, in forming *calves foot jelly*, and calves' heads are also employed to furnish jelly in making *mock turtle soup.* Gelatin is used not only to produce jellies, but to thicken and enrich gravies and sauces, and also as a clarifying or 'fining' agent to clear coffee or other mixtures.

430. **Different Names applied to these Substances.**—The recent rapid progress of organic chemistry, has brought this class of substances forward into new and highly interesting dietetical relations, and there has been a confusion in the terms applied to them, which, though perhaps inevitable, is at first very embarrassing to unscientific readers. As they all contain *nitrogen*, they are called *nitrogenous* alimentary principles; and as one of the names of nitrogen is *azote*, they are called *azotized* compounds. As they have all (except gelatin) the same composition as *albumen*, and are convertible into it, they are often called *albuminous* substances. As they form the material from which the body is nourished and built up, LIEBIG named them *plastic elements of nutrition;* they are also called *nutritive* principles, the *flesh-forming* and *blood-making* substances. MULDER supposed that a common principle could be separated from all of them by getting rid of sulphur, (of which they contain variable traces,) and he called this principle *protein*, and hence the group has been called *protein* or *proteinaceous* compounds. MULDER's peculiar views are abandoned, but his terms are still in current use.

3. COMPOUND ALIMENTS.—VEGETABLE FOODS.

431. Our common articles of diet consist of the alimentary principles which have just been noticed, combined together and forming what are known as *compound aliments.* They are naturally divided into *vegetable foods* and *animal foods;* of the former first.

A.—The Grains.

432. **Composition of Wheat.**—We begin with wheat, the prince of grains. It consists of gluten, starch, sugar, gum, oil, husk, and water, with salts that are left as ash when it is burned. It is maintained by some that there is really no sugar present in the ripe grain, especially in wheat, but that it is produced by the action of air and water upon the starch during the process of bread making, or analysis. The proportion of constituents in wheat is liable to considerable variation,

from many causes, as variety of seed, climate, soil, kind of fertilizers, seed, time of harvest, &c. We give five analyses.

	Vauquelin.		Dumas.		Beck.
	Flinty Wheat.	Soft Wheat.	Flinty Wheat.	Soft Wheat.	Genesee Wheat.
Water	12·00	10·00	12·00	10·00	12·40
Gluten	14·60	12·00	14·55	12·00	11·46
Starch	56·50	62·00	56·50	62·00	70·20
Sugar	8·50	7·40	8·48	7·36	5·20 (Sugar and Gum)
Gum	4·90	5·80	4·90	5·81	
Bran	2·30	1·20	2·30	1·29	
Total	98·80	98·40	98·73	98·46	99·26

433. **Proportion of Gluten in Wheat.**—It will be shown when we come to speak of the physiological influence of foods, that the most valuable portion, the strictly nutritious part, is that containing nitrogen, and that therefore 'gluten,' the properties of which have been noticed (426), is of the first importance in examining the grains. From an analysis of six samples of wheat, made by Vauquelin, we get an average of 11·18 per cent. of gluten; Dumas, from three samples obtained an average of 12·50 per cent.; and Dr. Lewis C. Beck, who made an investigation of the subject, at the direction of the Federal Government, and of 33 samples of wheat, gathered from all parts of the country, procured an average of 11·72 per cent. of this constituent, the specimens ranging from 9·85 to 15·25 per cent. The mode of examination, however, adopted by Dr. Beck—that of washing away the starch by a stream of water (426)—is not the most accurate. A portion of albumen and casein, with small particles of gluten, are carried away by the stream—which would make the remaining quantity an under-statement of the true proportion of nitrogenous matter. This loss is assumed to be compensated for by the oil retained in the gluten, and the result is thus to a certain degree guessed at. Horsford proceeded more accurately, by making an ultimate analysis of the wheat, and calculating the amount of nitrogenous matter by the quantity of nitrogen finally obtained. Six samples of wheat thus treated, yielded 15·14 per cent. of gluten. Quantities of gluten are mentioned by Davy and Boussingault as high as 20 or 30, and even 35 per cent., but these are probably erroneous over-statements. For general purposes we may adopt Dr. Beck's results—11·72 of gluten, or in even numbers 12 per cent.

434. **Quality of the Gluten of Wheat.**—But not only do wheats differ in the proportion of gluten, but also in its quality. In some it is more tough and fibrous, or 'sounder' and 'stronger,' than in others.

Moreover, any injury or damage that flour may sustain, is most promptly manifested by a change in the gluten; it is both reduced in quantity and diminished in tenacity. Flour dealers and bakers determine the quality of flours by making a few grains into a paste with water, when its value is judged of by the tenacity of the dough, the length to which it may be drawn into a thread, or the extent to which it may be spread out into a thin sheet. M. BOLAND has invented an instrument for determining the quality of gluten. A little cup-shaped copper vessel, which will contain about 210 grains of fresh gluten, is secured to a copper cylinder of three-fourths inch diameter and six inches long. It is then heated to about 420° in an oil bath. The gluten swells, and according to its rise in the tube so is its quality. Good flours furnish a gluten which will augment to four or five times its original bulk, while bad flours yield a gluten which does not swell, but becomes viscous and nearly fluid, adhering to the sides of the tube, and giving off occasionally a disagreeable odor, whilst that of good flour merely suggests the smell of hot bread.—(MITCHELL.)

435. **Macaroni** and **Vermicelli** are pastes formed from wheaten flour, and made to take various shapes by being passed through holes in metallic plates. Those flours are best adapted for this preparation which make the toughest paste; those, therefore, which are richest in gluten, and where this element is of the best quality. The wheat of southern or warm climates is said to abound most in gluten, and hence to be better fitted for this production. Our chief supplies of macaroni are from Italy. The English have attempted the manufacture by separating the gluten of one flour and incorporating it into another. Their success has been but indifferent, nor have we succeeded satisfactorily with it in this country. The best macaroni should retain its form, and only swell after long boiling, without either running into a mass or falling to pieces.

436. **Water in Wheat.**—The wheat grain consists of a solidified vegetable milk. As the grain ripens, evaporation of water takes place, and the milk condenses into a hard mass. Wheat ripened under the hot sun of this dry climate evaporates much of its water, and dries harder, with a tendency to shrivel in the berry; while in the cooler and damper climate of England longer time is allowed for ripening, and evaporation is slower, so that the same variety of English wheat presents a larger and plumper berry than if grown in this country. Dr. BECK's examination gave an average of 12·78 per cent. of water, the range being from 11·75 to 14·05. Different wheats, however, are stated to vary in their natural proportion of water so widely as from 5 to 20 per cent.

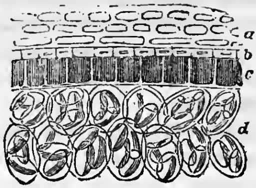
437. **Grinding of Grain.**—Grain is converted into flour by being ground between two horizontal stones, the upper of which revolves, while the lower is stationary. The mill-stones (buhr-stones) are composed of a peculiar hard and porous sand-stone, so that the working surfaces consist of an infinite number of minute cutting edges. There is an opening in the centre of the upper revolving stone through which the grains are dropped. The lower stone is convex and the upper one is concave, so as to match it; but they do not perfectly ioin or fit. From the centre outwards, they approach closer together, so that the grain is first coarsely crushed, and then cut finer and finer as it is carried to the circumference by the centre-flying (centrifugal) force. The crushed grain, as it leaves the stones, is not an absolutely uniform powder, composed of equal sized particles, but consists of parts which have been differently affected by the grinding process. Some are coarser, and others finer, so that it becomes possible to separate them. The ground mass is therefore conveyed away and bolted; that is, passed through a succession of sieves, and separated into several parts, fine flour, coarse flour, bran, &c.

438. **Structure of the Grains.**—When we consider wheat or other grain with reference to its grinding and sifting capabilities, the proportion and quality of its separated products, several things require notice in regard to the structure of the kernel or berry. Each grain consists of a farinaceous body, enclosed in a membranous husk or skin. This husky envelope varies in properties; in some wheat it is thin, smooth, and translucent; in others, rough, thick, and opaque; in some light-colored, in others dark; in some tough, in others brittle; and in some it peels or flakes off readily under the stones, and in others it is very adherent to the kernel. The other elements of the seed, albumen, gluten, starch, and oil, and the salts which it leaves as ash when burned (446), are not equally distributed throughout its mass. Immediately beneath the incrusting husk, is a layer of matter of rather a darkish color, and not very easily reduced to an impalpable powder. It is rich in gluten, and contains oil, which exists in minute drops enclosed in cells. Underneath this is the heart of the seed, which is whiter and more readily crumbles to a fine dust. This part consists more purely of starch, and forms the finest and whitest flour. There is a certain degree of interdiffusion of these elements throughout the body of the seed, yet, upon dissection, they are each found in excess in the parts indicated.

439. **Anatomy of Grains Illustrated.**—An idea may be gathered of this distribution of substances throughout the cereal seeds, by the accom-

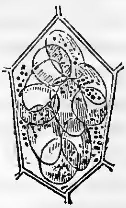
panying section of a grain of rye highly magnified (Fig 93): *a* represents the outer investing seed-coat, consisting of three rows of cells; *b*, an inner membrane or seed-coat, composed of a single layer of cells; *c*, a layer of cells containing gluten. These three form the bran; *d*, cells containing starch grains in the interior of the seed. Fig. 94 represents a cell containing starch, more highly magnified, and Fig. 95, the appearance of the grains of rye starch viewed by a still stronger power.

FIG. 93.



440. **Parts Separable by Sifting.**—These several portions oppose unequal resistance to the pulverizing force of the millstones. The outer fibrous portion which forms the bulk of bran is least affected; the tough coherent gluten is divided still finer, while the brittle starch, of which the grain is mainly composed, is crushed most completely. As the particles of these substances, therefore, are of different sizes, they may be separated by a bolting cloth, having different degrees of fineness of texture. The product is divided by the miller according to custom or fancy, four or five grades being often established, which, of course, vary much in composition and properties.

FIG. 94.



441. **Properties and Composition of Bran.**—From what has been said of the husk, it will appear that the quantity of bran yielded by different wheats, is liable to variation (438). As the husk is detached with different degrees of ease, it is evident that it may carry with it more or less adherent matter of the grain, by which its composition will be made to fluctuate. JOHNSTON states, that in good wheat the husky portion amounts to between 14 and 16 per cent. of its whole weight. The same authority found six wheats to yield bran of an average composition, as follows:

FIG. 95.

Water	13·1
Nitrogenized matter	19·3
Oil	4·7
Husk, and a little starch	55·6
Saline matter (ash)	7·3
	100

This discloses the nitrogenous matter, the oil, and the salts, in larger proportion than they exist in the interior of the seed. The excess of oil existing in the husks of wheat, helps to protect it against the penetration of moisture, and enables it to be washed (which ought always to be done before grinding), without wetting the inner part of the grain.

442. **White and dark-colored Flours.**—In separating flour into different grades, the finest and whitest will contain the largest quantity of starch, while the coarser will more abound in gluten, and present a darker color. From the soft wheats the bran peels off readily under the stones, and separates perfectly in bolting; and as these varieties contain least gluten, they yield the whitest or superfine flours. But the outer coating clings so closely to the hard or flinty sorts, that much of it is ground up finely with the flour, imparting to it a dark color, an effect which is also heightened by the larger proportion of gluten existing in the harder kinds. It is thus apparent that whiteness is *not* an indication of nutritive value of flour, but rather the reverse. We may add here, that flour of the first quality holds together in a mass when squeezed by the hand, and shows impressions of the fingers and even the marks of the skin *much longer* than when it is of inferior grade. The dough made with it is gluey, ductile, and elastic, easy to be kneaded, and which may be drawn out into long strips, or thinly flattened without breaking.

443. **Loss of Weight by Evaporation.**—When wheat is kept for several months, it loses water by evaporation, becomes denser, and one or two pounds a bushel heavier. When ground it gets hot, and still more of its moisture is evaporated, so that the flour and bran, although twice as bulky as the wheat, weigh some two or three per cent. less.

444. **Injurious changes in Flour.**—Wheaten flour becomes whiter with age, but it is at the expense of gradual deterioration of flavor, sweetness, and nutritive quality. BERGS kept various samples of flour, and found that the second and third qualities, *which contained most gluten*, were completely spoiled, after keeping only nine months, though preserved in casks in a cool, airy, and dry warehouse. MITCHERLICH and KROCKER showed that wheat in which sugar was proved to be absent before sending it to the mill, yielded, after being ground, 4 per cent. of it. Starch was thus transformed into sugar, which could not be done otherwise than through the internal action of the gluten aided by air and superabundant moisture (473). The mutual action of the gluten, and the natural moisture of the flour, seem often capa-

ble, at common temperatures, of slowly bringing about this injurious change. But when the flour comes out hot from the friction of the stones, and is left to cool gradually in large heaps, decomposition quickly sets in, starch is changed to sugar, and perhaps sugar to alcohol, and even alcohol to vinegar; so that the process advances rapidly to the souring stage. This action always takes place in the middle of the heap first, and proceeds towards the surface, the air enveloped in the flour, and the heat produced by chemical action, favoring the change most in the centre. Flour, as soon as ground, should therefore be conveyed to properly-constructed chambers, and quickly cooled, or if it be desired to preserve it for some time, it should be dried at a low heat. The amount of damaged flour thrown into the market is immense. Large quantities of it are due to careless and imperfect cooling, by which chemical changes are commenced, which time continues. Sometimes, to separate the bran most perfectly and procure the whitest flour, the miller moistens the grain previously to grinding; but if such flour is packed in barrels or sacks without artificial drying, it rapidly moulds and sours. From these considerations, we infer the desirableness of procuring flour for household use, freshly ground, and frequently from the mill, where that is practicable.

445. **Farina.**—A wheaten preparation under this name has come recently into general use, the same formerly known as 'pearled wheat.' It consists of the inner portion of the kernel of the finest wheat, freed from bran and crushed into grains, (*granulated*,) the fine floury dust and smaller particles being all removed. In cooking, it absorbs much water or milk, and forms an easily-digestible preparation, readily permeable by the juices of the stomach. In consequence of containing nitrogenous matter, it is greatly superior in nutritive power to cornstarch, arrowroot, tapioca, as a diet for invalids and children (746). Prof. J. C. Booth of Philadelphia, analyzed Hecker's Farina with the following results: Starch 60·4, nitrogenous matter 11·6, gum 2·9, sugar 2·41, bran 2·1, water 9·9. Professor Booth remarks: "The analysis is sufficient to show the excellent qualities of the farina, whether as a simple diet for invalids, or as an excellent food for the healthy."

446. **What Minerals exist in Wheat.**—When wheat is burned, there is left about 2 per cent. of ash, which consists of various mineral ingredients. An average of 32 of the most recent and reliable analyses gives the leading constituents, as follows: Phosphoric acid 46 per cent., (nearly half its weight,) potash 29·97, soda 3·30, magnesia 3·35, sulphuric acid ·33, oxide of iron ·79, and common salt ·09. Phos-

phoric acid is the characteristic and predominant element, potash and magnesia occurring next in the order of quantity. These mineral substances are unequally diffused throughout the seed. JOHNSTON has shown by an analysis of six samples of wheat, the ground product of which was divided into four qualities, that the mineral substances are distributed as follows. We give the average:—fine flour 1·08 per cent. next grade 3·8, coarser still 5·2, bran 7·2. The ash of bran contains considerable silica. The presence of these mineral substances is far from accidental, as was formerly supposed; we shall point out some of their important uses in the system when considering the physiological effects of food (690).

447. **Properties and Composition of Rye.**—This grain ranks next to wheat in bread-making and nutritive qualities. It produces a larger proportion of bran than wheat, yielding less flour, and that of a decidedly darker color. It contains more sugar than wheat, which accounts for the sweet taste which is peculiar to new rye-bread. Its husk has an aromatic and slightly acidulous flavor, which renders it agreeable to the palate. The bran should not, therefore, be entirely separated from the flour; for if the grain be ground fine and divested entirely of the husk, the bread will be deprived of much of its pleasant taste. The gluten of rye flour, although sufficiently tenacious to make good bread, is less tough and fibrous than that of wheat. Indeed it is more properly a kind of casein (424), or 'soluble gluten,' for when rye dough is washed with water, instead of remaining together in an adherent mass, its gluten diffuses itself throughout the liquid. Rye is generally stated to be less rich in the nutritive nitrogenous constituents than wheat. It has not been so thoroughly examined as that grain, but the analyses that have been made would seem to show that it is very little, if at all, inferior to it in nutritive power. BOUSSINGAULT obtained from the grain of rye 24 per cent. of bran, and 76 of flour. He separated by drying 17 per cent. of moisture, and the dry flour gave of

Rye (BOUSSINGAULT).	
Gluten, albumen, &c.	10·5
Starch	64·0
Gum	11·0
Fatty matter	3·5
Sugar	3·0
Epidermis and salts	6·0
Loss	2·0

Rye (POGGAILE).	
Nitrogenous matters	8·790
Starch and dextrin	65·533
Fatty matters	1·992
Lignin	6·383
Mineral matters	1·772
Water	15·530

A sample of rye dried in Prof. JOHNSTON's laboratory, lost 14·50 per cent. of water. HORSFORD examined four samples of European rye,

and obtained an average of 14 per cent. of water, and 13·79 per cent. nitrogenous compounds.

448. **Indian Corn or Maize.**—This grain is distinguished chemically by containing a larger proportion of oily or fatty matter than any other. It is quite rich in nitrogenous constituents, though less so than wheat. Its peculiar protein element takes the name of *zein* (from *zea maize*, the botanic name of Indian corn); it is not of a glutinous, adhesive nature, and hence maize flour or meal will not make a dough, or fermented bread. It is prepared in several forms. Its composition is given as follows:

Maize (Payen).		Yellow Maize (Poggaile).	
Starch	67·55	Nitrogenous matters	9·905
Gluten or zea	12·50	Starch, dextrin, sugar	64·535
Dextrin or gum	4·00	Fatty matter	6·680
Fatty matter	8·80	Lignin and coloring matter	3·968
Celulose	5·90	Mineral	1·440
Salts or ashes	1·25	Water	13·472
	100·00		

Horsford obtained 13·65 of nitrogenous matter from maize meal, and 14·66 from maize grain. *Samp* is Indian corn divested of its outside skin or bran, and of its germinal eye, the grain being left whole or nearly so. In *hominy* each grain is broken up into a number of smaller pieces. The meal of Indian corn, in consequence of its excess of oily matter, attracts much oxygen from the air, and is hence very prone to change, and does not keep well. This is the serious drawback of this most valuable grain; though cheap, nutritive and healthful, it is difficult to transport and preserve its meal, especially in warm seasons or climates.

449. **Oats.**—This grain is not employed to any considerable extent as an article of diet for man, in this country. The oat varies greatly in weight, ranging from 30 to 40 lbs. per bushel. In grinding, 30 lbs. give 16 of meal and 14 of husk, while a bushel weighing 40 lbs. yields 23 lbs. 6 oz. of meal and 16 lbs. 10 oz. of husk—the largest proportion of bran yielded by any grain, yet different varieties give different results. Oat flour stands before all other grains in point of nutritive or flesh-producing power, being first in its proportion of the nitrogenous element. It is also distinguished by its large quantity of fat or oil, ranging in this particular next to Indian corn. The following table gives the result of an analysis of French oats, by Boussingault, and the average of four samples of Scotch oats, by Prof. Norton.

(Boussingault).	
Starch	46·1
Sugar	6·0
Gum	8·3
Oil	6·7
Avenin, Albumen, Gluten	13·7
Husk, ash, and loss	23·7
	100·0

(Norton).	
Starch	65·10
Sugar	2·49
Gum	2·22
Oil	6·55
Avenin	16·50
Albumen,	1·42
Gluten	1·67
Epidermis	2·17
Alkaline, salt, and loss	1·84
	99·96

Norton's analysis, the most accurate we have, thus gives 19·59 per cent. of nitrogenous compounds. Again, from nine samples of dry oats he obtained 16·96 per cent. of protein compounds, the specimens ranging from 14 to 22 per cent. Prof. Horsford obtained from three samples an average of 12·83 per cent. water, and 16·59 protein constituents. From the dried grain he got 21·5 per cent. of these compounds. If oatmeal be mixed with water, it does not form a dough like wheat flour, and if it be washed upon a sieve, nearly the whole will be carried through, only the coarse parts of the meal remaining behind. The chief portion of the nitrogenized matter of the oat resembles casein more than gluten, and has received the name of *avenin* (from *avena*, the oat). Oatmeal, the ground and sifted flour of the grain, is not so white as wheaten flour, and has a somewhat bitterish taste. Under the husk of the oat there is a thin cuticle or integument, surrounding the central part, which is ground up with the meal, and not being sifted out, gives it a rough and harsh taste, and although the oatmeal gruel be strained, still a quantity of the sharp fragments of cuticle escape through the strainer. *Grits*, or groats, are oats in which the outer husk and cuticle are ground off and removed, so that grit gruel is 'smoother,' as it is termed. It is chiefly made into cakes, porridge, and gruel.

450. **Barley.**—The composition of barley is represented as follows:

Fine Barley Meal (Johnston).	
Starch	68
Fatty matter	2
Gluten, albumen, &c.	14
Water	14
Ash	2
	100

Barley (Pogoaile), later.	
Nitrogenous matters	10·655
Starch and dextrin	60·330
Fatty matters	2·384
Lignin	8·779
Mineral substances	2·623
Water	15·229

Einhof's analysis represents it as containing 4·62 of gum and 5·21 of sugar. Its husk or bran forms from 10 to 18 per cent. of its weight.

The composition of barley has not been very carefully examined. It is reported to contain a good share of nitrogenous matter, but of what nature is not known. It is deficient in true gluten and behaves like oatmeal when washed with water. When stripped of its husk or outer skin by a mill, it is called *hulled* or *pot-barley*, and is used for making broth. After a considerable portion more of the kernel has been ground off, the rounded and polished grains are known as *pearl-barley.*

451. **Rice** is remarkable for being richest in *starch* and most deficient in *oil* of all the cultivated grains. Its flesh-producing elements are low, much lower than wheat or Indian corn, and less than half that of oats. Analysis gives the following results:

Rice (Payen).		Rice (Poggaile).	
Starch	86·7	Starch, dextrin, sugar	74·470
Gluten, &c	7·5	Nitrogenous matters	7·800
Fatty matter	0·8	Fatty matters	2·235
Sugar and gum	0·5	Mineral	·326
Epidermis (skin)	3·4	Lignin	3·345
Saline matter (ash)	0·9	Water	17·730

Prof. Johnston found five varieties to contain an average of 13·4 per cent. of water and but ·41, that is less than half of one per cent. of ash. Mr. Horsford separated from some rice 15·14 per cent. of water, and 6·27 per cent. of nitrogenous matter in its ordinary state, and 7.4 per cent. in its dry state. It is usually presented to us in market hulled, or freed from its husk, and is used whole, being but rarely ground into flour.

452. **Buckwheat.**—The composition of this grain has not been satisfactorily elucidated; there remains considerable discrepancy in the results of its analysis. Zenneck found that in the dry state it consisted of—

Husk	26·9
Gluten, &c	10·7
Starch	52·3
Sugar and gum	8·3
Fatty matter	0·4

The gluten is here supposed to be estimated too high. Horsford obtained from buckwheat flour in the natural state (that is, not dried):

Water	15·12
Starch	65·05
Protein	5·84

B.—Leguminous Seeds.

453. **Composition of Peas.**—Seeds obtained from pods are called *leguminous*. Of this class we are only concerned with peas and

beans. They resemble much in composition the cereal grains, but are more highly nutritive; indeed, they afford the most concentrated form of vegetable nourishment. The roasted *chick-pea* of the East is considered to be more capable of sustaining life, weight for weight, than any other kind of food; hence, it is preferred by travellers about to cross the deserts, as the least bulky and heavy form of diet. According to HORSFORD and KROCKER:

A Table Pea yielded:		A Field Pea gave:	
Albumen and casein	28·02	Albumen and casein	29·18
Starch	38·81	Starch	66·23
Gum	28·50	Gum	66·23
Skin	7·65	Skin	6·11
Ash	3·18	Ash	2·79

According to POGGAILE, field peas that had been deprived of 9·5 [illegible] envelope, contained:

Nitrogenous matters	21·670
Starch, dextrin, and sugar	57·650
Fatty matters	1·920
Lignin	3·218
Mineral	2·802
Water	12·740

He found also in very soft green peas:

Nitrogenous matters	38·35
Older than the above	34·17
Ripened	27·72

Prof. JOHNSTON states that the proportion of nitrogenous, or flesh-forming matter, in both peas and beans, is on an average about 24 per cent., and of oil about two per cent. The nitrogenous element of peas and beans is not glutinous, and consists chiefly of vegetable casein. They are hence incapable of making bread. From their high proportion of nitrogenous constituents, peas and beans are extremely nutritious, ranking first among concentrated strength-imparting foods. They are considered difficult of digestion, and of a constipating quality, which requires to be corrected by admixture with other kinds of food. The varieties are numerous, with wide differences of flavor and softness when cooked, and they probably differ equally in composition. We have before stated, that in consequence of its abundance of casein, the Chinese make it up into a kind of vegetable cheese (424).

454. **Composition of Beans.**—The composition of beans varies but little from that of peas. The authorities above cited (HORSFORD and KROCKER) give the following results:

Beans (Horsford and Krocker).	Table Bean.	Large White Bean.
Vegetable casein and albumen	28·54	29·31
Starch	37·50	66·17
Gum	29·20	66·17
Skin	4·11	4·41
Ash	4·38	4·01

The peas and beans in this analysis were dried at 212°, and lost an average of 15.53 per cent. of moisture.

455. **Bone-producing material in Peas and Beans.**—By reference to the preceding analytical results, it will be seen that the ash, or mineral constituents of peas and beans, from which the earthy part of bones is derived, is considerable, but larger in beans than in peas.

Will and Fresinius' analyses of the ash of peas gave:	
Potash	39·51
Soda	3·98
Lime	5·91
Magnesia	6·48
Oxide of iron	1·05
Phosphoric acid	34·50
Common salt	3·71
Sulphuric acid	4·91

Three analyses of the ash of beans gave the following average result:	
Potash	29·62
Soda	13·31
Lime	6·11
Magnesia	8·95
Oxide of iron	0·98
Phosphoric acid	4·84
Chlorine	1·18
Sulphuric acid	1·43
Silica	5·34

C.—Fruits.

456. **Their General Composition.**—Although fruits are extensively used as articles of diet, yet as staple sources of nutrition they bear no comparison to the grains. They consist of pulpy masses, which are nearly all water, and are prized far more for those properties which relate them to the *taste* than for nourishing or strengthening power. They generally consist of from 75 to 95 per cent. water, from 1 to 15 or 20 per cent. fruit sugar, organic acids in variable proportions (414) in combination chiefly with lime and potash, pectine, or the jelly-producing principle, ligneous skins and cores, with peculiar aromatic and coloring principles of infinite shades of diversity. The unripe fruits contain a larger proportion of water and acid, and a less amount of sugar than the natural fruits. As they contain so great a proportion of watery juices, they are very prone to change, and thus exhibit little constancy of composition. From this circumstance, and the numberless varieties of fruits that are catalogued, and also from the fact that comparatively little attention has been given to this branch of organic chemistry, our knowledge of the exact composition of fruits is very imperfect.

457. **Composition of Apples.**—Every one will understand that the

various sorts of apples differ much in composition, yet in an average condition 100 lbs. of fresh apples contain about 3·2 lbs. of fibre, 0·2 lbs. of gluten, fat, and wax, 0·16 of casein, 1·4 of albumen, 3·1 of dextrine, 8·3 of sugar, 0·3 of malic acid, 82·66 of water. Besides the above mentioned bodies, the apple contains a small quantity of tannic and gallic acid—most in the russets. To these acids apples owe their astringency of taste, and the blackening iron or steel instruments used to cut them. The following is the proportion of water and dry matter in several varieties of apples, according to SALLSBURY's examination.

	Talman Sweeting.	Greening.	Swarr Apple.	Roxbury Russet.	English Russet.
Water.......	81·52	82·85	84·75	81·35	79·21
Dry Matter..	18.48	17·15	15·25	18·65	20·79

The percentage of ash in the apple is small, yet it is rich in phosphoric and sulphuric acids, potash, and soda. The proportions of water and dry matter have also been determined in the following substances:

	Watermelon.	Muskmelon.	Cucumber.
Water............................	94·89	90·98	96·36
Dry Matter.........................	5·10	9·01	3·63

The dry matter of melons contains quite a large percentage of albumen, casein, sugar, and dextrin, with a small quantity of acid.

D.—Leaves, Leaf-Stalks, &c.

458. Many kinds of leaves abound in principles adapted for animal nutrition, as is shown by the extent to which cattle are grown, sustained and fattened upon the grasses. Man makes use of leaves in his diet to but a limited extent. Professor JOHNSTON remarks, "leaves are generally rich in gluten; many of them, however, contain other substances in smaller quantity associated with the gluten, which are unpleasant to the taste, or act injuriously upon the general health, and therefore render them unfit for human food. Dried tea-leaves, for example, contain about 25 per cent. of gluten; and therefore if they could be eaten with relish and digested readily, they would prove as strengthening as beans or peas."

459. **The Cabbage.**—The same authority says of this vegetable: "It is especially nutritious. The dried leaf contains, according to my analysis, from thirty to thirty-five per cent. of gluten; and is in this respect, therefore, more nutritious than any other vegetable food which is consumed to a large extent by men and animals. I know, indeed, of only two exceptions,—the mushroom, which in its dry matter contains sometimes as much as 56 per cent. of gluten, and the dried cauliflower in which the gluten rises, as high as 64 per cent."

The cabbage and cauliflower lose in drying more than 90 per cent. of water; and the dried residue, according to PEREIRA, is remarkably rich in sulphur as well as nitrogen. The plant decays quickly, and gives out a strong odor of putrefaction, owing to its nitrogenous and sulphurous compounds. Decayed cabbage leaves should therefore not be allowed to remain in cellars, or lie about in the vicinity of dwellings.

460. **Lettuce Leaves** are much used at table as a salad. The young leaves contain a bland, cooling juice; but as the plant advances, its milky juice becomes bitter, and is found to contain opium. In this stage it has a slight tendency to promote sleep. The *water-cress*, leaves of *white mustard* and of *common cress*, probably owe their pungency to a minute portion of sulphurized volatile oil, analogous to that found in *horseradish.* The stalks of many kinds of leaves, as *spinach*, *turnip-tops*, *potato-tops*, *cowslips*, *&c.*, are used as greens, but their peculiar characters have not been ascertained. The stalks of *rhubarb*, used for pies, puddings, &c., like apples and gooseberries, contain much malic and oxalic acid in combination with lime and potash. The proportion of water, dry matter, and ash, in the rhubarb stalk, celery, and vegetable oyster, is as follows:

	Rhubarb Stalks.	Celery.	Vegetable Oyster.
Water........................	89·50	88·22	84·46
Dry Matter....................	10·50	11·77	15·54
Ash..........................	1·13		

Half the dry matter consists of malic, tartaric, and oxalic acids, with fibre, sugar, albumen, and casein.

E.—Roots, Tubers, Bulbs and Shoots.

461. **Composition of Potatoes—Water.**—This is the most widely cultivated and important for dietetical purposes of all the root tribe, and has been more carefully examined than any other. Like fruits and leaves its leading constituent is water, which composes about three-quarters of its weight. Young, unripe potatoes contain more water than those fully grown, and it has been found that the 'rose' end of the potato, or that part from which the young shoots spring, contains more water than the 'heel' or part by which it is attached to the rootlet. KÖRTE examined 55 varieties of potato and found them to contain 75 per cent. of water and 25 of solid matter. Professor JOHNSTON gathered from 27 analyses made in his laboratory the following results. Greatest proportion of water in young potatoes, 82 per cent.; largest proportion in full grown potatoes, 68·6 per cent.

He gives the mean of 51 determinations upon potatoes of all ages—as water 76 per cent., dry matter 24.

462. **Starch in Potatoes.**—A large part of the solid matter in potatoes consists of starch. JOHNSTON states as the results of numerous experiments, that the proportion is in the natural state 64·20 per cent. SIEMENS ascertained the proportion of starch in 66 varieties to range between 19·25 and 11·16 per cent.; the average being 15·98. These proportions, however, vary with the kind of potato, soil, season, and other circumstances. The heel end usually contains more starch than the rose end. The weight of potatoes and their proportion of starch diminishes by keeping. PAYEN found the same variety to yield of starch in

October	17·2 per cent.	February	15·2 per cent.
November	16·8 "	March	15 "
December	15·6 "	April	14·5 "
January	15·5		

Other experiments would seem to show that there is rather an *increase* after digging; but all examinations agree, that as vegetation becomes active in the spring, the buds begin to grow at the expense of the starch contained in the tuber, and hence at this season potatoes are less mealy, and not so much esteemed for table use.

463. **Flesh-producing constituents of Potatoes.**—The potato contains a considerable proportion of nitrogenous matter in the threefold form of albumen, casein, and gluten, as it exists in the grains. They exist dissolved in its juices. There is more of the casein than of the other elements. JOHNSTON gives the average of these constituents at 1-4th per cent. in the natural state, and 5-8th per cent. when freed from water. But he acknowledges his mode of separating them to be liable to error, so that the figures are probably too low. HORSFORD, by a more accurate method, found the percentage of these compounds in the dry matter of potatoes to be—in white potatoes 9·96 per cent., in blue 7·66 per cent. He found also that not only is the proportion different in different varieties, but that it is greater in young potatoes than in old; and BOUSSINGAULT also found the proportion of the protein compounds to diminish the longer the potato is kept.

464. **Woody Fibre, Sugar, Gum.**—The proportion of fibre in the potato varies from $1\frac{1}{2}$ to 10 per cent., and may be said to average about 3. The fatty matter is also variable, but may be stated at about 1 per cent. Sugar in the natural state about 3·3, gum 0·55, or in the dry condition, sugar 13·47, gum 2·25.

465. **Average Composition of Solid or Dry Matter of Potato.**—This is summed up by Professor JOHNSTON in round numbers as follows:

Starch	64
Sugar and gum	15
Protein compounds	9
Fat	1
Fibre	11
Total	100

The dry potato, therefore, is about equal in nutritive value to rice, and is not far behind the average of our finer varieties of wheaten flour. The juice of potatoes is acid; it was formerly supposed to contain citric acid, but it is now ascertained to be due to malic acid, and perhaps the sulphuric and phosphoric found in the ash. Potatoes also contain a small portion of asparagin, the peculiar principle of asparagus. When potatoes are freed from their large excess of water, so as to bring them into just comparison with the grains in composition, they are found to contain quite a large percentage of mineral matter left as ash—the average of six determinations giving 3·92 per cent. The constituents of these six samples give an average as follows:

Potash	55·75
Soda	1·86
Magnesia	5·28
Lime	2·07
Phosphoric acid	12·57
Sulphuric acid	13·64
Silica	4·23
Peroxide of iron	0·52
Common salt	7·01

The carbonic acid, which was from 6 to 12 per cent., was deducted. The mineral matter of the potato seems to be thus distinguished from that of the grains by its large proportion of potash, sulphuric acid, and common salt, and its lesser quantity of phosphoric acid and magnesia.

466. **The Onion.**—This bulbous root abounds in nitrogenous matter; when dried, it has been found to yield from 25 to 30 per cent. It is therefore highly nutritive. It contains a strong-smelling sulphurized oil, the same that gives its powerful odor to the garlic. The constituents of the onion are thus stated by PEERIRA:

Volatile oil,	Woody fibre,
Uncrystallizable sugar,	Pectic and phosphoric acid,
Gum,	Phosphate and carbonate of lime,
Vegetable albumen,	Iron.

467. **Beets.**—The varieties of beets of course differ in composition, but they all contain much sugar. Their nutritive qualities are not well determined. Beetroot is represented as containing 81 per cent

of water, 10·20 of sugar, and 2·03 of nitrogenous matter. In the long blood-beet there is 89·09 per cent. of water, and 10·90 of dry matter.

468. **Turnips, Carrots, Parsnips.**—Chemistry has hitherto cast but an uncertain light upon the composition of this class of substances. It appears from the best determinations, that the proportion of solid matter in several roots is as follows:

White Turnips	10½
Yellow do.	13½
Mangel-wurzel	15
Carrot	14

The dry substance of these roots is much lower than that of the potato, which ranges at 25 per cent. Yet the flesh-forming constituents of dried turnips much exceed those of the potato, as the following comparison shows.

	Protein Compounds.	
The dried potato	8	per cent.
Yellow turnip	9½	do.
Mangel-wurzel	15½	do.

The nitrogenous matter of dried mangel-wurzel being nearly twice as great as in the dried potato. In the carrot the proportion of water is 85·78, and dry matter 14·22. According to CROME, the parsnip contains—

Starch	1·8
Albumen	2·1
Gum	6·1
Sugar	5·5
Fibre	5·1
Water	79·4
Total	100·00

4. COMPOUND ALIMENTS—ANIMAL FOOD.

A.—Constituents of Meat.

469.—Various parts of animal bodies contribute materials for diet; the flesh and fat chiefly, but nearly all other portions, blood, intestines, membranes, bones, and skin, more or less. The staple constituents of animal food are fibrin, albumen, gelatin, fat, salts, and water, and in the case of milk, casein and sugar.

470. **Composition of Flesh-meat.**—This is generally understood to signify the muscular or lean parts of cattle, surrounded by fat, and containing more or less bone. The muscles consist of fibrin; they are separated into bundles by membranes, and into larger separate masses by cellular tissues, in which fat is deposited. The fleshy mass is pene-

trated by a network of blood-vessels and nerves, and the whole is distended by water, which composes about three-fourths of the weight of the meat. The composition of the muscular flesh of different animals, according to Mr. BRANDE, is as follows:

	Water.	Albumen and Fibrin.	Gelatin.	Total solid matter.
Beef	74	20	6	26
Veal	75	19	6	25
Mutton	71	22	7	29
Pork	76	19	5	24
Chicken	73	20	7	27
Cod	79	14	7	21

These results give an average of very nearly 75 per cent. water. LIEBIG assumes it at 74, with 26 per cent. of dry matter. The ratio of water in meat, fowl, and fish, is quite uniform, ranging from 70 to 80 per cent., but the proportion of the other constituents, muscular fibre, fat, and bone, exhibits the widest possible diversity. In some animals, more especially wild ones, as deer, &c., there may be hardly a trace of oily matter, while swine are often fed until the animal becomes one morbid and unwieldy mass of fat. The pure muscular flesh of ordinary meat, with all its visible fat separated, is assumed by KNAPP and LIEBIG to contain still about 8 per cent. of fat. In beef and mutton, such as is met with in our markets, from a third to a fourth of the whole dead weight generally consists of fat.—(JOHNSTON.)

471. **Juice of Flesh.**—The true color of the fibrin of meat is white, yet flesh is most commonly of a reddish color (flesh-color). This is due to a certain portion of the coloring matter of the blood, by which it is stained. Yet the liquid of meat is not blood; when that has been withdrawn from the animal, and the blood-vessels are empty, there remains diffused through the muscular mass a peculiar liquid, known as the juice of flesh. It consists of the water of flesh, containing about 5 per cent. of dissolved substances, one-half of which is albumen, and the other half is composed of several compounds, not yet examined. The juice of flesh may be separated by finely mincing the meat, soaking it in water, and pressing it. The solid residue which remains after all the soluble matter has been thus removed, is tasteless, inodorous, and white like fish. The separated juice is uniformly and strongly acid, from the presence of lactic and phoshporic acids, hence it is in the opposite state to that of the blood, which is invariably alkaline. The juice of flesh contains the savory principles which give taste to meat, and which cause it to differ in different animals. It also contains two remarkable substances, called *kreatine* and *kreatinine*, nitrogenous compounds, which may be crystallized. The quantity yielded

is variable in different kinds of flesh, but in all is extremely small. Kreatine is a neutral or indifferent substance, while kreatinine is a powerful organic base, of a similar nature with theine and cafeine of tea and coffee.

472. **Blood, Bones, and Internal Organs.**—The leading constituents of blood are the same as flesh ; it contains only some three per cent. more of water. Its nitrogenous matter, however, is chiefly liquid albumen. Blood has been called liquid flesh, and flesh solidified blood. About half the weight of bones is mineral matter, lime combined with phosphoric acid, forming phosphate of lime—the substance that we have seen to abound so greatly in the ash of grains. The other half of bones is gelatin, the thickening principle of soups (*glue*). It is sometimes partially extracted for this purpose by boiling. *Marrow* is a fatty substance, enclosed in very fine cellular tissue within the bone. Skin, cartilage, and membrane, yield much gelatin. The *tongue* and *heart* are muscular organs, agreeing in dietetical properties with lean flesh. BRACONNOT's analysis of the *liver* gives 68 per cent. of water, and 26 of nitrogenous matter; it also contains oil. The *brain* is a nervous mass, containing 80 per cent. water, some albumen, and much of a peculiar phosphoric oily acid. The *stomachs* of ruminating animals which yield *tripe*, are principally composed of fibrin, albumen, and water.

473. **Composition of Eggs.**—The eggshell is a compound of lime, not the phosphate as exists in bones, but chiefly carbonate of lime. It is porous, so as to admit of air for the wants of the young animal in hatching, and usually weighs about one-tenth of the entire egg. The white of egg consists of water containing 15 or 20 per cent. of albumen. The yolk is water and albumen, but contains, also, a large proportion (two-thirds of the dried yolk) of a bright yellow oil, containing sulphur and phosphoric compounds. A common-sized hen's-egg weighs about a thousand grains, of which the *shell* weighs 100, the *white* 600, and the yolk 300. The composition of its contents is:

Water	74
Albumen	14
Fat	10·5
Ash (salts)	1·5
Total	100

B.—Production and Composition of Milk.

474. **What it Contains.**—This familiar liquid consists of oil or butter sugar, casein or the cheesy principle, and salts, with a large proportio of water. The sugar, casein, and salts are dissolved in the wate

while the butter is not, but exists diffused through the liquid in the form of numberless extremely minute globules. They cannot be seen by the naked eye. When the light falls upon them they diffuse it in all directions, so that the mass appear opaque and white. Viewed by a microscope, the globules appear floating in a transparent liquid. In respect of its sugar, casein, and salts, milk is a *solution;* but with reference to its oily part, it is an *emulsion.* It is heavier than water in the proportion of about 103 to 100, although it differs considerably in specific gravity. When first drawn it is slightly alkaline and has a sweetish taste, which is due to the sugar of milk.

475. **Proportion of its Elements.**—This is variable. It generally contains about 86 per cent. water, 4 to 7 of casein, 3·5 to 5·5 of butter, and 3 to 5·5 of sugar of milk and salts. The following are analyses by HENRY and CHEVALIER:

	Cow.	Woman.
Casein	4·48	1·52
Butter	3·13	3·55
Milk sugar	4·47	6·50
Salts	·60	0·45
Water	87·02	87·98

The following are HADLEIN's results:—The second column is the average of two analyses.

	Cow's Milk.	Woman's Milk.*
Butter	3	2·35]
Sugar of milk and salts soluble in alcohol	4·6	3.75
Casein and insoluble salts	5·1	2·90
Water	87·3	90·50

476. **Circumstances Influencing the Quality of Milk.**—Both the quantity and quality of milk are influenced by various conditions appertaining to the animal. Its food exerts a powerful control in this respect. Green succulent food is more favorable to the production of milk than dry, and R. D. THOMSON's experiments go to show that of dry food, the richest in nitrogenous matter best promotes the milk secretion. PLAYFAIR was led, by his brief experiments, to conclude that food low in nitrogenous matters (as potatoes) yielded a large quantity of milk which was rich in butter, and that quiet (*stall feeding*) had the same effect, whilst cows grazing in the open air upon poor pasture, and consequently obliged to take much exercise, yielded

* The milk of women from 15 to 20 years of age, contains more solid constituents than of women between 30 and 40. Women with dark hair also give a richer milk than women with light hair. In acute diseases the sugar decreases one-fourth, and the curd increases one-fourth; while in chronic affections the butter increases one-fourth, and the casein slightly diminishes. In both classes of diseases the proportion of saline matter diminishes.—(JOHNSTON.)

milk rich in casein. It appeared from THOMSON's observations, that the produce of milk of a cow, with *uniform* diet, gradually diminished, and increased again by a *change* of diet. It is well known that a cow fed upon *one* pasture will yield more cheese, while upon another it will give more butter. Hence the practice in dairy districts of allowing the animal to roam over a wide extent of pasture to seek out for itself the kind of herbage necessary to the production of the richest milk; hence, also, the propriety of adding artificial food to that derived from grazing. Plants and weeds found scattered in many pastures are apt to affect, injuriously, the quality and taste of the milk. Butter is especially liable to be deteriorated in this way. An observing dairy-manager remarks as follows: "If a cow be fed on ruta-baga, her butter and milk partake of that flavor. If she feeds on pastures where leeks, garlicks, and wild onions grow, there will be a still more offensive flavor. If she feeds in pastures where she can get a bite of brier leaves, beech or apple-tree leaves, or any thing of the kind, it injuriously affects the flavor of the butter though not to the same extent, and would scarcely be perceptible for immediate use. So with red clover. Butter made from cows fed on red clover is good when first made, but when laid down in packages, six months or a year, it seems to have lost all its flavor, and generally becomes more or less rancid as the clover on which the cow fed was of rank and rapid growth."—(A. B. DICKINSON.)

477. **Distance from the time of calving.**— The *colostrum*, or first milk which the cow gives for several days after the birth of her young, differs from normal milk. GREGORY states that it contains from 15 to 25 per cent. of albumen, with less casein, butter, and sugar of milk A much larger quantity of milk is yielded in the first two months after calving, than at the subsequent periods; the decrease is stated as follows, according to AYTON:

	Quarts per day.			Quarts.
First 50 days	24	or in	all	1200
Second "	20	"	"	1000
Third "	14	"	"	700
Fourth "	8	"	"	400
Fifth "	8	"	"	400
Sixth "	6	"	"	300

and at the end of ten months, they become nearly or altogether dry.

478. **Time of year, age and condition of the animal.**—In spring, milk is finest and most abundant. Moist and temperate climates and seasons are favorable to its production. In dry seasons the *quantity* is less, but the quality is richer. SPRENGEL states that cool weather favors the production of cheese and sugar in the milk, while hot weather

increases the product of butter. The poorer the apparent condition of the cow, good food being given, the richer, in general, is the milk; but it becomes sensibly poorer when she shows a tendency to fatten. A state of comparative repose is favorable to all the important functions of a healthy animal. Any thing which frets, disturbs, torments, or renders her uneasy, affects these functions, and among other results, lessens the quantity, or changes the quality of the milk. Such is observed to be the case when the cow has been newly deprived of her calf—when she is taken from her companions in the pasture-field—when her usual place in the cow-house is changed—when she is kept long in the stall after spring has arrived—when she is hunted in the field, or tormented by insects, or when any other circumstance occurs by which irritation or restlessness is caused, either of a temporary or of a permanent character.—(JOHNSTON.)

479. **Production and Composition of Cream.**—We have stated that butter exists in milk, as a fatty emulsion; that is, not dissolved, but floating as exceedingly minute globules throughout the watery mass. These butter globules are lighter than water, and hence, when the milk is suffered to stand undisturbed, they slowly rise to the surface, forming *cream*. The oil-globules of cream do not coalesce or run together, they are always separated from each other, and surrounded by the soluble ingredients of milk; while at the same time, the body of the milk never becomes perfectly clear by the complete separation of these globules. Hence, cream may be viewed as milk rich in butter, and skimmed milk as containing little butter. It is supposed by some, that the butter particles are in some way invested or enclosed with casein; at all events, a quantity of cheesy matter rises with the oil-globules. Its proportion in cream depends upon the richness of the milk, and upon the temperature at which it is kept during the rising of the cream. In cool weather, the fatty matter will bring up with it a larger quantity of the curd, and form a thicker cream.

480. **Conditions of the Formation of Cream.**—The globules of butter being extremely minute, and but slightly lighter than the surrounding liquid, which is at the same time somewhat viscid or thick, they of course ascend but slowly to the surface. The larger globules of butter, which rise with greater ease, mount first to the surface. If the first layer of cream, consisting of these largest particles, be taken off after 6 or 12 hours, it affords a richer, fresher, and more palatable butter than if collected after 24 or 30 hours standing. Milk is, therefore, sometimes skimmed twice, and made to yield two qualities of butter. The deeper the milk, the greater the difficulty with which the

oily matter ascends through it; hence, it is customary to set the milk aside in shallow pans, so that it may not be more than two or three inches in depth; hence, if it is desired to prevent the formation of cream, the milk should be kept in deep vessels. *Temperature* powerfully influences the formation of cream, or the rapidity with which it rises. Heat, by increasing the thinness and limpidity of the liquid, and the lightness of the oil-globules, favors their ready ascent; while cold, by thickening the liquid, and solidifying the oil, greatly retards their separation. Hence it is said, that from the same milk an equal quantity of cream may be extracted, in a much shorter time during warm than during cold weather; that, for example, milk may be perfectly creamed

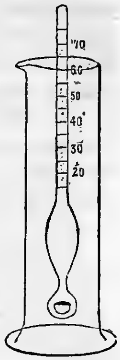
In 36 hours when the temperature of the air is			....	50° F.
" 24	"	"	"	55°
" 18 to 20	"	"	"	68°
" 10 to 12	"	"	"	77°

while at a temperature of 34° to 37° (two to five degrees above freezing), milk may be kept for three weeks, without throwing up any notable quantity of cream.—(SPRENGEL.)

481. **Milk Creams before it is taken from the Cow.**—This spontaneous tendency of milk to separate itself mechanically into two sorts or qualities, explains the remarkable difference in the richness of milk withdrawn at different stages of the milking process. The glands in the teats of the animals, which secrete the milk, are vessels interlaced with each other in such a way as to form hollow spaces or reservoirs which distend as the milk is secreted. In these reservoirs the same thing takes place as occurs in an open vessel, and with still more facility as the temperature is up to blood heat (98°)—the rich creamy portion rises above, while the poorer milk falls below. Hence that which is first drawn is of an inferior quality, while that which is last drawn, the *strippings* or *afterings*, abounds in cream. Professor ANDERSON states, that compared with the first milk the same measure of the last will give at least eight, and often sixteen times as much cream. The later experiments of REISET show, that where the milkings are 11 or 12 hours apart, the quantity of butter in the last drawn milk is from three to twelve times greater than that obtained from the first drawn milk. Where the milkings were more often, the difference became less. As milk before being taken from the cow is already partially separated—its richer from its poorer parts—the dairy manager should take advantage of this circumstance, and not commingle in the same vessel the already half-creamed milk, if the object is the separation of butter. It has been shown that more cream is obtained

by keeping the milk in separate portions as it is drawn, and setting these aside to throw up their cream in separate vessels, than when the whole milking is mixed together. Moreover, the intimate mixture of the richer and poorer portions not only reduces the quantity of cream that may be separated, but much delays the operation which, in hot weather, when milk soon sours, is objectionable.

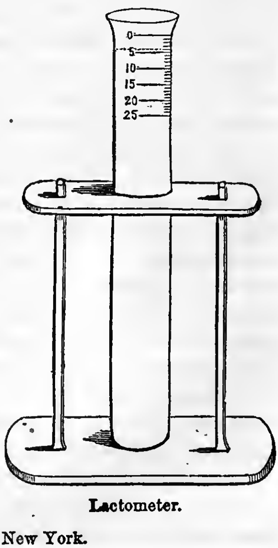
FIG. 96.



Hydrometer.

482. **Determining the value of Milk.**—Its value is proportional to the amount of its solid alimentary constituents, and is liable to variation, according to circumstances. If butter is to be manufactured from it, that is most valuable which contains most oily matter; if cheese is desired, then that which contains most casein. Milk is heavier than water, and the richer it is the heaver it is; hence it has been attempted to make the latter quality a guide to the former. Its weight compared with water, or *specific gravity*, is determined by the *hydrometer* (Fig. 96). A tin or glass cylinder is filled with milk to be tested, and the hydrometer, a glass bulb with a stem above, is placed in it; the lighter the milk, the deeper it sinks; the heavier it is, the higher it floats. A scale is marked upon the stem, which indicates at once how far the weight of the milk rises above pure water. Yet the results of the instrument are to be received with caution. Milks, though pure, differ naturally in specific gravity; while it is easy to add adulterating substances that shall increase their weight, thus causing the hydrometer to report them *rich*. Yet as giving an important indication it has value, and with experience and judgment, may be made useful.* An instrument called the *lactometer* (milk measurer) has been used to determine the proportion of cream. It consists of a glass tube ten or twelve inches long, marked off and numbered into a hundred spaces. The tube being filled with milk to the top space, is suffered to stand until the

FIG. 97.



Lactometer.

* Made by TAGLIABUE, of New York.

cream rises to the surface, when its per cent. proportion is at once seen. It will answer if only the upper portion of the tube be marked as shown in Fig. 97. The percentage of cream, that is, the thickness of its stratum at the top of the tube, varies considerably. We have found the average to be $8\frac{1}{2}$ per cent., although samples are liable to range much above and below this number.* If the milk has been mixed, say with one-third water, the cream will fall to 6, if with one-half, it may fall to 5 per cent.

483. **Mineral Matter in Milk.**—The proportion of salts in milk averages about half per cent.; that is, 200 lbs. when dried and burned will yield 1 lb. of ash. The composition of this ash is shown by the analysis of HAIDLEIN, who obtained from 1000 lbs. of milk

	1	2
Phosphate of lime	2·31 lbs.	3·44 lbs.
Phosphate of magnesia	0·42 "	0·64 "
Phosphate of peroxide of iron	0·07 "	0·07 "
Chloride of potassium	1·44 "	1·83 "
Chloride of sodium	0·24 "	0·34 "
Free soda	0·42 "	0·45 "
Total	4·90	6·77

III.—CULINARY CHANGES OF ALIMENTARY SUBSTANCES.

1. COMBINING THE ELEMENTS OF BREAD.

484. **General Objects of Culinary Art.**—We have seen that the materials employed as human food consist of various organized substances derived from the vegetable and animal kingdoms, grains, roots, stalks, leaves, flowers and fruit, with flesh, fat, milk, eggs, &c. &c. But few of these substances are best adapted for food in the condition in which they occur naturally. They are either too hard, too tough, insipid or injurious, and require to undergo various changes before they can be properly digested. Most foods, therefore, must be subjected to processes of manufacture or cookery before being eaten. In their culinary preparation, numerous mechanical and chemical alterations are effected, in various ways; but the changes are chiefly wrought by means of water and heat. Water softens some substances, dissolves others, sometimes extracts injurious principles, and serves an important purpose in bringing materials into such a relation that they may act chemically upon each other. Heat, applied through the medium of water, or in various ways and degrees, is the chief agent of culinary transformations. Another proper object of cooking is the preparation of palatable dishes,

* The number given by the lactometer will, from the nature of the case, be somewhat *under* the truth, as the butter globules do not all ascend through the long column of milk.

from the crude, tasteless, or even offensive substances furnished by nature. This involves, not only the alterations produced by water and heat, but the admixture of various sapid and flavoring ingredients, which increase the savory qualities of food. The cereal grains, converted into flour and meal, are to be prepared for mastication, mixture with the saliva, and stomach digestion. This end is best accomplished by converting them into bread, while at the same time they assume a portable and convenient form, and are capable of being preserved for a considerable time. Bread is made, as is well known, by first incorporating water with the flour, and making it into *dough*, and then by various means causing it to *rise*, that is, to expand into a light, spongy mass, when, after being moulded into loaves, it is finally submitted to the action of heat in an oven, or baked. We shall consider the successive steps of this important process, in the order of their occurrence; and as the flour of wheat is the staple article in this country for the manufacture of bread, it will occupy our first and principal attention.

485. **Water absorbed in making Dough.**—The addition of much water to flour forms a thick liquid, called batter; more flour admixed stiffens it to a sticky paste, and still more worked through it produces a firm *dough.* The water thus added to flour does not remain loosely associated with it, but enters into intimate combination with its constituents, forming a compound, and is not all evaporated or expelled by the subsequent high heat of baking. In the dough, the liquid performs its usual office of bringing the ingredients into that closer contact which is favorable to chemical activity. As water is thus made to become a permanent part of solid bread, it is important to understand in what proportion, and under what conditions, its absorption takes place. Baked bread that has been removed from the oven from 2 to 40 hours, loses, by thorough drying at 220,° from 43 to 45 per cent. of its weight, or an average of 44 per cent. If we assume the flour to contain naturally 16 per cent. of water, 10½ lbs. of the 44 that was lost belonged to the flour itself, while 33½ lbs. were artificially added in making the dough. Thus—

Dry flour	56	66½
Water in flour naturally	10½	
Water added in baking		33½
		100

Ten pounds of flour would thus absorb 5 lbs. of water, and yield 15 lbs. of bread. The best flours absorb more water than those of inferior quality. The amount with which they will combine is supposed to depend upon the proportion of gluten. In dry seasons flour

will bear more water than in wet, and a thorough process of kneading will also cause the dough to absorb a larger quantity without becoming the less stiff on that account. Certain substances added to flour augment its property of combining with water (521).

486. **Effects of the Kneading Process.**—The purpose of water intermingled with flour is to combine with and hydrate the starch, to dissolve the sugar and albumen, and to moisten the minute particles of dry gluten, so as to cause them to cement together, and thus bind the whole into a coherent mass. But, as only a certain limited quantity of water can be employed to produce these results, it is obvious that it must be carefully and thoroughly worked throughout the flour—this is called *kneading* the dough, and is generally performed with the hands. The process is laborious, and attempts have been often made to accomplish it by machinery, but hitherto without success. Flours differ so much in their dough-making properties, that *judgment* is required in managing them. As the eye cannot penetrate into the interior of the doughy mass to ascertain its condition, we have no guide equal to the sense of touch. Differences of consistence, foreign substances, dry lumps of flour, are readily distinguished by the hand of the kneader, who is also by *feeling* able to control the gradual and perfect admixture of water, yeast, and flour, better than any machine *yet devised.* Much of the excellence of bread depends upon the thoroughness of the kneading, the reasons of which will soon be apparent. At first the dough is very adhesive, and clings to the fingers, but it becomes less so the longer the kneading is continued, and when the fist upon being withdrawn leaves its perfect impression in the dough, none of it adhering to the hand, the operation may be discontinued.

487. **Bread from plain Flour and Water.**—When dough, made by simply working up flour and water, is dried at common temperatures, a cake is produced, not very hard, but which is raw, insipid, and indigestible. If baked at 212° (ordinary steam heat), a portion of the starch becomes soluble, but the cake is dense, compact, and very difficult of digestion. If baked at a still higher heat, and afterward subjected to prolonged drying, we have the common *ship-bread* or *sea-biscuit*, which is made in thin cakes and never in large loaves, and which is very dry, hard, and difficult to masticate, although it has an agreeable taste, derived from the roasting of the surface of the dough. Bread prepared in this manner lacks two essential characters,—sufficient softness to be readily crushed in the mouth or chewed, and a looseness of texture or sponginess by which a large surface is exposed to the

action of the digestive juices in the stomach. To impart these qualities to bread, the dough is subjected to certain operations before baking, which are technically called *raising*. The capability of being raised is due to the gluten. By the mechanical operation of kneading, the glutinous parts of the flour are rendered so elastic that the mass of dough is capable of expanding to twice or thrice its bulk without cracking or breaking. Various methods are employed for this purpose, which will now be noticed; and first of fermentation:

2.—Bread Raised by Fermentation.

488. **Substances capable of Putrescence.**—It is a remarkable property of the nitrogenous alimentary principles, that when in a moist state, and exposed to atmospheric oxygen, they speedily enter upon a state of change or rapid decay. They are of very complex composition (422), the attractions of their atoms being so delicately adjusted that slight disturbing forces easily overturn them. Oxygen of the air seizes upon the loosely held atoms, breaks up the chemical fabric, and produces from its ruins a new class of substances—the gaseous products of putrefaction. Thus, it is well known that flesh, blood, milk, cheese, dough, bread, all of which are rich in nitrogenous substances, will preserve their properties in the air only a short time, but pass into a state of putrescence, becoming sour and nauseous, and sending forth offensive exhalations. This change is called *putrefaction*, and the compounds which are liable to it, *putrefiable* substances.

489. **The Putrefactive change Contagious.**—The other class of aliments, the *non-nitrogenous*, are in this respect of a very different nature. They contain fewer atoms, lack the fickle element nitrogen, and have a simpler and firmer composition. When pure starch, gum, sugar, or oil, are exposed to the air in a moistened state, they exhibit little tendency to change, and give rise to none of the effects of putrefaction. Yet if placed in contact with putrefying substances, the change proves contagious; they catch it, and are themselves decomposed and destroyed. Hence, when the putrefiable substances are considered, *with reference to the effects they produce upon the other class*, they take a new name, and are called *ferments*. The communication of that condition of change from one class to the other, is called *fermentation*, and the substances *acted upon* are named *fermentable* compounds. Thus, if some sugar be dissolved in water, and a portion of putrefying dough, meat, or white of egg be added to it, *fermentation* sets in; that is, the change is communicated to the sugar, the balance of its affinities is destroyed, and two new substances—one alcohol, containing all

the hydrogen of the sugar, and the other carbonic acid, containing two-thirds of its oxygen—are produced.

490. **Conditions of Fermentation.**—When matter capable of putrefaction begins to change, decomposition rapidly spreads throughout the mass. If a small portion of putrefying substance be added to a large quantity, in which it has not commenced, the change extends until the whole becomes alike affected. But it is not so in fermentation. The sugar cannot catch the infection and then go on decomposing itself. It can only break up into new compounds as it is *acted upon*, and when the limited quantity of ferment made use of is exhausted, or spent, the effect ceases, no matter what the amount of fermentable matter present. Two parts by weight of ferment decompose no more than one hundred of sugar. Temperature controls the *rate* or activity of fermentation. At 32° no action takes place; at 45° it proceeds slowly; at 70° to 86°, which is the proper range of warmth, it goes on rapidly. The operation may be stopped by the exhaustion of either the ferment or the sugar, by drying, by exposure of it to a boiling heat, and by various chemical substances, as volatile oils, sulphurous acid, &c.

491. **Different kinds of Fermentation.**—When nitrogenous matters are just beginning to decompose, the action is too feeble to establish the true alcoholic fermentation in solutions of sugar. Yet even in this early stage they can change the sugar, not breaking it to pieces so completely, but splitting each of its atoms into two equal atoms of *lactic acid*, the sour principle of milk. This process is called the *lactic acid* fermentation, while that in which alcohol is produced is the *vinous* or alcoholic fermentation. If this be not checked, the process is liable to run on to another stage; the ferment is capable of attacking the alcohol itself, and converting it to *acetic acid*, the active principle of vinegar. This is the *acetous* fermentation. There are several conditions of this acetous change. *First*, a spirituous or alcoholic solution; *second*, a temperature from 80° to 90°; *third*, a ferment to give impulse to the change; and, *fourth*, access of air, as oxygen is rapidly absorbed in the process, combining with and oxidizing the alcohol.

492. **Dough raised by Spontaneous Fermentation.**—Now dough, as it contains both gluten and sugar, when moistened is capable of fermentation without adding any other substance. If simple flour and water be mixed and set aside in a warm place, after the lapse of several hours it will exhibit symptoms of internal chemical action, becoming sour from the formation of lactic acid, while minute bubbles appear, which are owing to a gas set free within the dough. The changes are irregular and un-

certain, according to the proportion and condition of the constituents of the flour. They also proceed with greater or less rapidity at the surface or in the interior, accordingly as the parts are exposed to the cooling and oxidating influence of the air. Bread baked from such dough, is sour, heavy, and altogether bad. Yet the true vinous fermentation may be spontaneously established in the dough, by taking measures to quicken the action. If a small portion of flour and water be mixed to the consistency of batter (its half-fluid state being favorable to rapid chemical change), and the mixture be placed in a jar or pitcher and set in a vessel of water, kept at a temperature from 100° to 110°, in the course of five or six hours decomposition will have set in, with a copious production of gas bubbles, which may be seen by the appearance of the batter when stirred. If this be now mixed and kneaded with a large mass of dough, moulded into loaves and set aside for an hour or two in a warm place, the dough will swell, or '*rise*' to a much larger bulk; and when baked, will yield a light spongy bread. A little salt is usually added at first, which promotes the fermentation, and hence, bread raised in this manner is called 'salt raised bread.' Milk is often used for mixing the flour, instead of water; the product is then called 'milk-emptyings bread.'

493. **What makes the Dough rise?**—The cause of the rising is the vinous fermentation produced by the spontaneous change of the gluten or albumen which acts upon the sugar, breaking it up into alcohol and carbonic acid gas. If the fermentation is regular and equal, the kneading and intermixture thorough, and the dough kept sufficiently and uniformly warm, the production of gas will take place evenly throughout the dough, so that the bread when cut will exhibit numberless minute cavities or pores, equally distributed throughout. For its capability of being raised, dough depends upon the elastic and extensible properties of its gluten, which is developed by the admixture of water with flour. Hence the proper quantity of water is that which imparts to the gluten the greatest tenacity; an excess of it lowering the adhesiveness of the glutinous particles. The toughness of the gluten prevents the small bubbles of gas from uniting into larger ones, or from rising to the surface. Being caught the instant they are produced, and expanding in the exact spot where they are generated, they swell or raise the dough. All rising of bread depends upon this principle—the liberation of a gas evenly throughout the glutinous dough. No matter what the mode of fermentation, or what the substances or agents employed instead of it, they all bring about the result in the same way.

494. **Raising Dough by Leaven.**—But the mode of raising dough by spontaneous fermentation (492) is not sufficiently prompt and convenient; we require some readier means of establishing immediate decomposition. If we take a piece of dough which has been kept sufficiently long to ferment and turn sour, and then knead it up thoroughly with a large lump of fresh dough, the whole of the latter will shortly enter into a uniform state of fermentation; and if a little of this be reserved for the next baking, it may be worked into a fresh mass of dough, and in this way, active fermentation may be induced at any time. Fermenting dough thus used is called *leaven*. It may be made from any sort of flour, and is improved by the addition of pea and bean meal, which ferment easily. When properly made, leaven may be kept weeks or months fit for use, and by adding a portion of dough to the leaven, as large as that reserved for the bread-maker, the stock of leaven is always kept up. Although leaven when added to dough, awakens the true alcoholic fermentation, yet being in a sour state, it produces a portion of lactic acid, and often acetic acid; the latter being mostly driven off in the process of baking, while the former remains in the bread. Hence, bread made with leaven always has a distinctly sour taste, partly caused by the acid of the leaven itself, and partly by the sour fermentation which it induces in the dough. It is difficult to manage, and requires much skill to produce a good result. Leaven is but little used in this country, bread being almost universally raised by means of *yeast*.

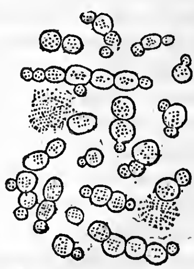
3. Properties and Action of Yeast.

495. **Production of Brewer's Yeast.**—When grains are placed in the proper conditions of germination, that is, moistened and exposed to atmospheric oxygen at the proper temperature, a portion of their gluten is changed to the state of ferment, and acquires the property of transforming starch into sugar. Hence, seeds in germinating become sweet. Barley placed in these conditions, begins to germinate, swells, softens, and turns sweet; it is then heated and dried, by which the process is stopped. The barley is then called *malt*. It is next crushed or ground and infused (*mashed*) in water at 160° so as to extract all the soluble matter it contains. The liquid (*sweet-wort*) is then boiled to coagulate the excess of vegetable albumen. Hops are added, to impart a bitter taste to the product (beer), and also to regulate the subsequent fermentation. The cooled wort is then run into the fermenting vat, and yeast is added. "In three or four hours, bubbles of gas will be seen to rise from all parts of the liquid; a ring of froth,

forming at first around its edge, gradually increases and spreads till it meets in the centre, and the whole surface becomes covered with a white creamy foam. The bubbles of gas (*carbonic acid*) then rise and break in such numbers, that they emit a low hissing sound, and the white foam of yeast continues to increase in thickness, breaking into little pointed heaps, which become brownish on the surface and edges; the yeast gradually thickening until it forms a tough, viscid crust." Although a portion of the yeast was spent in the operation, yet a much larger quantity has been produced from the nitrogenous matter of the grain in the solution.

496. **Appearance of Yeast—It is a Plant.**—Yeast, as usually procured from the brewer, is a yellowish gray or fawn-colored frothy liquid, of a bitter taste, and which shrinks in a few hours into one-fourth the space it occupied at first. When fresh, it is in constant movement, and bubbles of gas escape from it. When dried it loses 70 per cent. of its weight, becomes solid, horny-looking, half-transparent, and breaks readily into gray or reddish fragments. The nature of yeast was for a long time matter of doubt and speculation, but the microscope has at length cleared up the question, and showed that it is a true plant belonging to the Fungus tribe. Under a powerful magnifier, it is seen to consist of numberless minute rounded or oval bodies, which are true vegetable *cells*. Each little globule consists of an enveloping skin or membrane, containing a liquid within. Such cells are the minute agencies by which all vegetable growth is affected. The leaves and pulpy parts of plants are built up of them, as a wall is built of bricks. All the numberless substances produced by plants, are generated within these little bodies. They grow or expand from the minutest microscopic points and seem to bud off from each other, as shown in Figs. 98 and 99. The little grains from which they spring or germinate are shown, and how they multiply by budding. They are of amazing minuteness, a single cubic inch of yeast, free from adhering matter, containing as many as eleven hundred and fifty-two millions of them. In what manner yeast acts to decompose sugar is not known. The yeast is destroyed or expends itself in producing the effect, yet it furnishes none of its substance to join with the sugar, in producing alcohol and carbonic acid. LIEBIG supposes the effect to be *dynamic*, that is, produced by an impulse of force; the

FIG 98.

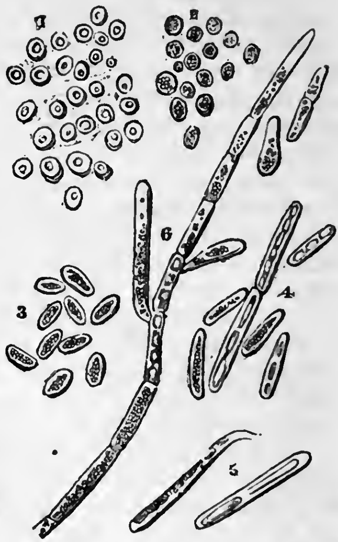


Yeast cells, showing how they multiply by budding, and by granules or seeds escaping from their interior.

motions of the atoms of the decomposing ferment, being communicated to the atoms of sugar, set these also in motion, by which the sugar structure is, as it were, jarred and shaken to pieces, its atoms falling into new arrangements and forming new substances.

497. **Domestic preparation of Yeast—Fowne's method.**—But, as many have no access to breweries, it is desirable to know how to make yeast at home. If common wheaten flour be mixed with water to a thick paste, and exposed slightly covered, and left to spontaneous change in a moderately warm place, it will, after the third day, begin to emit a little gas, and to exhale an exceeding disagreeable sour odor. After the lapse of some time this smell disappears; the gas evolved is greatly increased, and is accompanied with a distinct agreeable vinous odor; this will happen about the sixth or seventh day, and the substance is then in a state to excite fermentation. An infusion of crushed malt (wort) is then boiled with hops, and when cooled to 90° or 100°, the altered dough, above described, after being thoroughly mixed with a little lukewarm water, is added to it, and the temperature kept up by placing the vessel in a warm situation. After a few hours fermentation commences, and when that is complete, and the liquid clear, a large quantity of excellent yeast is formed at the bottom.

FIG. 99.



A developed yeast plant, the numbers indicating the successive stages of growth.

498. **Yeast from Potatoes.**—Boil half a dozen potatoes in three or four quarts of water, with a couple of handfuls of hops placed in a bag. Mash the potatoes and mix with the water, adding and stirring in a little salt, molasses and flour, until it is of a battery consistence. Then mix in a couple of spoonfuls of active yeast. Place before the fire, when it will soon begin to ferment. In a cool place it may be kept for weeks.

499. **Action of Hops in Yeast-making.**—Hop-flowers contain about 8 per cent. of a brownish yellow bitter volatile oil, upon which its peculiar odor depends. The hop has been long known for its soporific or sleep-producing properties, which are supposed to be due to this volatile narcotic oil. When dry hop-flowers are beat, rubbed and sifted, they yield about 8 per cent. of fine yellow dust—an aromatic resin, which has an agreeable odor, and a bitter taste. When taken internally it has a soothing, tranquillizing, sleep-provoking influence. It is called *lupulin.* Hops also contain a considerable proportion of another strong bitter principle, which is said not to be narcotic. In brewing, the chief use of hops is to impart an agreeable bitterness to the beer, but it also has the effect of arresting or checking fermentation before all the sugar is converted into alcohol, and then preventing the production of acid. It is also well-known that in the domestic preparation of yeast, hops serve to prevent the mixture from souring, though *how* this is affected we cannot tell.

500. **Yeast preserved by drying.**—The liquid, or active yeast, is liable to turn sour and spoil in warm weather, losing its properties and imparting to bread a most disagreeable flavor. Drying has therefore been resorted to, as a means of preserving it. On a large scale, it is pressed in bags and dried at a gentle heat, until it loses two-thirds of its weight of water, leaving a granular or powdery substance, which, if packed and kept from the air and quite dry, may be preserved a long time. It is curious that *mechanical* injury kills or destroys yeast. Falls, bruises, a rough handling spoils it, so that great care is required to remove it from place to place. LIEBIG remarks that simple pressure diminishes the power of yeast to excite the vinous fermentation. Yeast is also preserved by dipping twigs in it and drying them in the air. Or it may be worked round with a whisk until it becomes thin, and then spread with a brush over a piece of clean wood and dried. Successive coats may be thus applied, until it becomes an inch or two in thickness. When thoroughly dried, it can be preserved in bottles or canisters. Yeast is also commonly preserved by adding to it maize meal, and making it into a dough which is wrought into cakes and dried. They may be kept for months and are ready for use at any time, by crumbling down and soaking a few hours in warm water. We add minuter directions for making yeast-cakes. Rub three ounces of fresh hops until they are separated, boil half an hour in a gallon of water, and strain the liquid through a fine sieve into an earthen vessel. While hot, stir in briskly 3½ lbs. of rye flour. Next day, thoroughly mix in 7 lbs. of Indian meal, forming a stiff dough; knead it well, roll

12

it out a third or half an inch thick, cut into cakes and dry in the sun, turning every day and protecting from wet. If preserved perfectly from damp they will keep long.

501. **Bitterness of Yeast—how corrected.**—Yeast is often so bitter as to communicate a most disagreeable taste to bread. This may be derived from an excess of hops. To rectify this, mix with the yeast a considerable quantity of water, and set it by to rest for some hours, when the thickest part will fall to the bottom. Pour off the water which will have extracted a part of the bitter principle, and use only the stiff portion that has fallen to the bottom. But yeast sometimes acquires a bitter taste from keeping, which is quite independent of that derived from the hops. One method of remedying this, consists in throwing into the yeast a few clean coals freshly taken from the fire, but allowed to cool a little on the surface. The operation appears to depend in principle upon the power of freshly burnt charcoal to absorb gases and remove offensive odors (811).

502. **Acidity of Yeast—how corrected.**—In country places, where it is customary to keep yeast for some time, and especially during the warmth of summer, it is very liable to sour. In such case, it may be restored to sweetness, by adding a little carbonate of soda or carbonate of magnesia, only so much being used as may be necessary to neutralize the acidity.

503. **Dough raised by Yeast.**—How fermentation lightens dough, has been shown (493). Yeast produces these changes promptly and effectually. It is mixed with a suitable portion of water, flour, and salt, to form a stiff batter, which is placed near the fire for an hour or two, covered with a cloth. This is called *setting the sponge.* An active fermentation is commenced, and the carbonic acid formed in the viscid mass, causes it to swell up to twice its original size. If not then quickly used it *falls,* that is, the accumulated gas within escapes, and the dough collapses. Yet after a time it may again rise, and even fall a second time and rise again. This, however, is not allowed. When it has fully risen, much more flour is thoroughly kneaded with the sponge, and the dough is left for perhaps an hour and a half, when it rises again. It is then again kneaded and divided into pieces of the proper size for loaves. The loaves should be moulded with care, as too much handling is apt to cause the escape of the enclosed gas, and make the bread heavy.

504. **Correction of Acidity in Dough.**—Dough is frequently sour from an acid condition of the flour. It may be in this condition from a sour state of the yeast, or the fermentation may be so feeble as to

produce acid (476), or it may be too active and rapid, if too much or too strong yeast has been used; or in hot weather when the dough is liable to sour by running into the acetous fermentation. If the difficulty is too sluggish a change, it should be hastened by securing the most favorable warmth. If, on the contrary, it is too violent, it may be checked by uncovering the dough, and exposing it to the air in a cool place. If the dough be already sour, it may be sweetened by alkaline substances. Carbonate of soda will answer this purpose. Carbonate of ammonia is perhaps better, as it is a volatile salt, and is raised in vapor and expelled by the heat of the oven (510). If too much be used, a portion of the excess is driven off by the heat, and in escaping assists in making the bread lighter. Caution should, however, be employed to use no more alkali than is really necessary to neutralize the acid. When the acidity is but slight, it may be rectified by simply kneading the dough with the fingers moistened with an alkaline solution.

505. **The Sugar of Flour all decomposed in Dough.**—It is at the expense of sugar destroyed that fermented bread is raised, but *how much* sugar is thus decomposed is variously stated, and depends upon the activity and continuance of fermentation. Experiments would seem to show, that all the sugar present is rarely, if ever, destroyed. The raised dough and bread both contain sugar, often nearly as much as the flour before it was used. This is explained by remembering that one of the effects of fermentation is to change starch to sugar.

506. **How much Alcohol is produced in Bread.**—Of course the quantity of alcohol and carbonic acid generated in bread is in exact proportion to the amount of sugar destroyed, which, as we have said, is by no means constant. In an experiment, a pound of bread occupied a space of 60 cubic inches, 26 of which were solid bread, and 34, cell-cavities; consequently 34 cubic inches of carbonic acid of the heat of the oven were generated to raise it, which implied the production of about 15 grains of alcohol, or less than one-quarter of one per cent. of the weight of bread. It has been attempted to save this alcohol, which is vaporized and driven off into the air by the baking heat, but the product obtained was found to be so small as not to pay cost. It is also a current statement, that alcohol exists in the bread, contributing to its nutritive qualities. We have never found it there, and never saw a chemical analysis of bread that enumerated it as a constituent.

4. Raising Bread without Fermentation.

507. **Objections to raising by Ferment.**—Two or three objections have been urged against raising bread by fermentation. *First*, the loss of

a portion of the sugar of the flour which is decomposed; this loss, however, is trifling, and the objection futile. It is said, *secondly*, that as a destruction or incipient rotting process has been established in the dough, bread made from it cannot be healthful. This is only *fancy*, experience is wanting to show that well-made fermented bread is injurious. *Thirdly*, it is said that the fermenting process is not only uncertain, but slow, and requires more time than it is often convenient to allow. There is such force in this latter objection, that means have been sought to replace fermentation by some quicker and readier method of raising the dough.

508. **How it is done without Ferment.**—As the lightening and expansion of the dough are caused by gas generated within it, it would seem that we may adopt any means to produce such a result. It is commonly done in two ways; either by mixing chemical substances with the flour, which, when brought into contact and wet, act upon each other so as to set free a gas, or by introducing into the dough a volatile solid substance, which, by the heat of baking, rises into the state of gas. In the first case, substances are used which set free carbonic acid; in the second case, a compound of ammonia.

509. **Raising Bread with Chemical Substances.**—Bicarbonate of soda and hydrochloric acid are used for raising bread. The soda is mixed intimately with the flour, and the acid is added to the water requisite to form dough. PEREIRA indicates the following proportions:

Flour	1 lb.
Bicarbonate of soda	40 grains.
Cold water, or any liquid necessary	½ pint.
Hydrochloric acid	50 drops.

The soda and flour being mixed, the acidulated water is added gradually, with rapid stirring, so as to mix speedily. Divide into two loaves, and put into a hot oven immediately. The acid combining with the soda, sets free its carbonic acid, which distends the dough. Both the acid and the alkali disappear, are destroyed, and the new substance formed by their union is chloride of sodium, or *common salt;* so that this means of raising bread answers also to salt it. If the ingredients be pure, the proportions proper, and the mixture perfect, no other substance will remain in the bread. If the acid be in excess, there will be sourness; and if there be too much alkali, or if it be not entirely neutralized, unsightly yellow stains in the bread crumb will be apparent, accompanied by the peculiar, hot, bitter, alkaline taste, and various injurious effects. The changes that take place are thus shown. We begin with—

BICARBONATE OF SODA; (*solid*,) and HYDROCHLORIC ACID; (*liquid*,)	and get, in the dough,	CARBONIC ACID; (*gas*,) WATER; (*liquid*,) and COMMON SALT; (*solid*.)

Bread is also raised with soda powders;—tartaric acid, and bicarbonate of soda, which are the active ingredients in effervescing draughts. The changes are these

BICARBONATE OF SODA; (*solid*,) and TARTARIC ACID; (*solid*,)	produce, in the dough,	CARBONIC ACID; (*gas*,) and TARTRATE OF SODA; (*solid*.)

Cream of tartar, consisting of tartaric acid combined with and partly neutralized by potash, is also used with soda, one being mixed with flour, and the other dissolved in water. Double the quantity of cream of tartar to soda is commonly used, but of tartaric acid only an equal, or slightly less quantity. In these cases tartrate of soda is formed in the bread, which, in its action upon the system, is like cream of tartar —gently aperient. Preparations which are known as *egg-powder*, *baking-powder*, and *custard-powders*, consist of bicarbonate of soda and tartaric acid, mixed with wheat flour or starch, and colored yellow with *turmeric*, or even poisonous chromate of lead. The difficulty with these powders, is to get them in perfect neutralizing proportions. This may be ascertained by dissolving them in water; the mixture should be neutral to the taste, and produce no effervescence by adding either alkali or acid. Sour milk, or buttermilk, are often used with soda or saleratus. In these cases the lactic acid they contain combines with the alkali, forming lactate of soda, or potash, and setting carbonic acid free, which lightens the dough, just as in all the other instances.

510. **Sesquicarbonate of Ammonia.**—The perfect theoretic conditions of raising bread without ferment would be, to find a solid substance which could be introduced into the flour, but which would entirely escape as a gas during baking, raising the bread, and leaving no trace of its presence. Carbonate of ammonia complies with the first of these conditions; it is a solid which, under the influence of heat, is decomposed entirely into gases. Thus—

SESQUICARBONATE OF AMMONIA; (*solid*,)	in baking produces,	AMMONIA; (*gas*,) BICARBONATE OF AMMONIA; (*gas*,) CARBONIC ACID, (*gas*.)

Yet practically these gases do not all escape in baking; a portion of them is apt to remain, communicating a disagreeable hartshorn flavor. All these methods have one common and serious disadvantage—the gas is set free too suddenly to produce the best effect. Alum and carbonate of ammonia are sometimes used; they act more slowly, but leave an unwholesome residue of alumina and sulphate of ammonia in the bread.

511. **Important Caution in reference to the Chemicals used.**—The class of substances thus introduced in the bread are not *nutritive* but *medicinal*, and exert a disturbing action upon the healthy organism. And although their occasional and cautious employment may perhaps be tolerated, on the ground of convenience, yet we consider their habitual use as highly injudicious and unwise. This is the best that can be said of the chemical substances used to raise bread, even when pure, but as commonly obtained they are apt to be contaminated with impurities more objectionable still. For example, the commercial muriatic acid which is commonly employed along with bicarbonate of soda, is always most impure—often containing chlorine, chloride of iron, sulphurous acid, and even arsenic, so that the chemist never uses it without a tedious process of purification for his purposes, which are of far less importance than its employment in diet. While common commercial hydrochloric acid sells for 3 cents per pound wholesale, the purified article is sold for 35. Tartaric acid is apt to contain lime, and is frequently adulterated with cream of tartar, which is sold at half the price, and greatly reduces its efficacy; while cream of tartar is variously mixed with alum, chalk, bisulphate of potash, tartrate of lime, and even sand. Sesquicarbonate of ammonia is liable by exposure to air to lose a portion of its ammonia. It is hence seen that the substances we employ are not only liable to injure by ingredients which they may conceal, but that their irregular composition must often more or less defeat the end for which they are intended. We may suggest that, in the absence of tests, the best practical defence is to purchase these materials of the druggist rather than the grocer. If soda is desired, call for the *bicarbonate* of soda; it contains a double charge of carbonic acid, and is purest. Soda-saleratus is only the crude, impure carbonate—soda-ash. The cream of tartar should appear white and pure, and not of a yellowish tinge (698).

512. **Raising Dough with Oily Substances and Eggs.**—If dough be mixed with butter or lard, rolled out into a thin sheet, and covered with a thin layer of the oily matter, then folded, rolled and recoated from 2 to 10 times, and the sheet thus produced be submitted to the oven, the

heat causes the disengagement of elastic vapor from the water and fatty matter, which, being diffused between the numerous layers of dough, causes them to swell up, producing the flaky or puffy appearance which is seen in *pastry*. This kind of lightness must not be confounded with that produced by the other methods described; for, although the layers are partially separated, yet the substance of each stratum is dense and hard of digestion. The albumen of eggs, when smartly beaten, becomes frothy and swells, by entangling much air in its meshes. If then mixed with dough, it conveys with it air bubbles, which are expanded in baking. From its glairy, tenacious consistence when mixed with dough or pudding, it encloses globules of gas or steam, which are generated by fermentation or heat. In this way eggs contribute to the lightness of baked articles.

513. **Raising Gingerbread.**—Gingerbread usually contains so much molasses that it cannot be fermented by yeast. But the molasses is of itself always acidulous, and takes effect upon the saleratus, setting free carbonic acid gas. Sour milk, buttermilk, and cream, are also used, which act in the same way upon the carbonate of soda or potash, and thus inflate the dough. Dr. Colquhoun has found that carbonate of magnesia and tartaric acid may replace the saleratus (and alum also, which is sometimes used), affording a gingerbread more agreeable and wholesome than the common. His proportions are, 1 lb. of flour, $\frac{1}{2}$ oz. carbonate of magnesia, $\frac{1}{8}$ oz. of tartaric acid, with the requisite molasses, butter, and aromatics.

5. Alterations Produced in Baking Bread.

514. **Temperature of the Oven.**—Bread is usually baked by heat radiated or conducted from the brick walls or iron plates of which ovens are made. The oven should be so constructed that the heat may be equal in its different parts, and remain constant for a considerable time. If the heat be insufficient, the bread will be soft, wet, and pasty; if on the other hand the heat be too great at first, a thick, burnt crust is produced, forming a non-conducting carbonaceous covering to the loaf, which prevents the heat from penetrating to the interior. Hence a burnt outside is often accompanied by half-raw dough within. If, however, the temperature be proper, the heat passes to the interior of the loaf and produces the necessary changes before the outside becomes thickly crusted. If we cut open a well baked loaf, immediately from the oven, and bury the bulb of a thermometer in the crumb, it will rise to 212°. This heat is sufficient to

carry on the inner chemical changes of baking, and it is obvious that the heat cannot rise above this point so long as the loaf continues moist (65.) Bread might be baked at a temperature of 212° (by steam), but then it would lack that indispensable part, the crust. The baking temperature of the oven ranges from 350° to 450° or 500°, and bakers have various means of judging about it. If fresh flour strewn upon the oven bottom turns brown, the heat is right, if it chars or turns black, the heat is too great.

515. **Heat causes a loss of Weight.**—The loaf loses a portion of its weight by evaporation. The quantity thus lost depends chiefly upon the size and form of the loaf. If it be small or thin, it will part with more water in proportion than if of cubical shape. Something depends upon the quality of the flour and the consistence of the dough. Various experiments would seem to show that bread parts with from one-sixth to one-tenth of its weight in baking. In those places where bread is required by law to be of a certain weight, this loss must be calculated upon and a proportionate amount of additional flour used. PRECHTL states from experiment that loaves which, after baking and drying, weigh one pound, require that an extra weight be taken, in dough, of six ounces; if the loaves are to weigh three pounds, twelve ounces additional must be taken, and if six pounds, sixteen ounces.

516. **How Heat enlarges the Loaf.**—When the loaf is exposed to the heat of the oven, it swells to about twice its size. This is owing to the expansion of the carbonic acid gas contained in its porous spaces, the conversion of water into steam, and the vaporizing of alcohol, which also rises into the gaseous form and is driven off, as is shown by the spirituous odor yielded in the baking process.

517. **Chemical Changes in producing the Crust.**—The heat of the oven falling upon the surface of the loaf causes first the rapid evaporation of its water, and then begins to produce a disorganization of the dough. The starch-grains are ruptured (530) and its substance converted into gum; as the roasting continues chemical decomposition goes on, and organic matter is produced of a brown color, an agreeable bitter taste, and soluble in water, which has received the name of *assamar*. The formation of hard crusts on the loaf may be prevented by baking it in a covered tin, or, it is said, by rubbing a little melted lard over it after it is shaped and before it is set down to rise.

518. **Chemical Changes in producing the Crumb.**—As the temperature within the loaf does not rise above 212°, no changes can go on there except such as are produced by the heat of the aqueous vapor. This is sufficient to stop the fermentation, destroy the bitter principle of

the yeast, and kill the yeast plant. In baking about one-fourteenth of the starch is converted into gum, the rest is not chemically altered, as may be shown by moistening a little bread-crumb and touching it with solution of iodine, when the blue color will prove the presence of starch. The gluten, although not decomposed, is disunited, losing its tough, adhesive qualities. The gluten and starch-paste are intimately mixed, but they do not unite to form a chemical compound.

519. **Moisture contained in Bread.**—In newly-baked bread the crust is dry and crisp, while the crumb is soft and moist, but after a short time this condition of things is quite reversed. The brown products of the roasting process attract moisture and the crust gets daily softer, while the crumb becomes dry. Bread, two or three days old, loses its softness, becoming hard and crumbly. But this apparent dryness is not caused by evaporation or loss of water, for it may be shown by careful weighing that stale bread contains almost exactly the same proportion of water as new bread that has become completely cold. The change to dryness seems to be one of combination going on among the atoms of water and bread. That the moisture has only passed into a state of concealment may be shown by exposing a stale loaf in a closely covered tin for half-an-hour to a boiling heat, when it will again have the appearance of new bread. The quantity of water which well-baked wheaten bread contains amounts, on an average, to about 45 per cent. The bread we eat is, therefore, nearly one-half water. It is, in fact, both meat and drink together. One of the reasons why bread retains so much water is, that during the baking a portion of the starch is converted into gum, which holds water more strongly than starch does. A second is, that the gluten of flour when once thoroughly wet is very difficult to dry again, and that it forms a tenacious coating round every little hollow cell in the bread, which coating does not readily allow the gas contained in the cell to escape, or the water to dry up and pass off in vapor; and a third reason is, that the dry crust which forms round the bread in baking is nearly impervious to water, and, like the skin of the potato we bake in the oven or in the hot cinders, prevents the moisture from escaping.—(Johnston.)

520. **Qualities of Good Bread.**—In baking bread, it is desirable to avoid the evils of hardness on the one hand and pastiness on the other, nor should it be sour, dense, or heavy. It should be thoroughly and uniformly kneaded, so that the carbonic acid will not be liberated in excess in any one place, forming large hollows and detaching the crumb from the crust. The vesicles should be numerous, small, and

equally disseminated; nor should the crust be bitter and black, but of an aromatic agreeable flavor. "If the yeast be so diffused throughout the whole mass as that a suitable portion of it will act on each and every particle of the saccharine matter at the same time, and if the dough be of such consistency and temperature as not to admit of too rapid a fermentation, then each minute portion of saccharine matter throughout the whole mass will, in the process of fermentation, produce its little volume of air, which will form its little cell, about the size of a pin's head and smaller, and this will take place so nearly at the same time in every part of the dough, that the whole will be raised and made as light as a sponge before the acetous fermentation takes place in any part. And then, if it be properly moulded and baked, it will make the most beautiful and delicious bread, perfectly light and sweet, without the use of any alkali, and with all the gluten and nearly all the starch of the meal remaining unchanged by fermentation."—(GRAHAM.)

6. INFLUENCE OF FOREIGN SUBSTANCES UPON BREAD.

521. **Common Salt, Alum, &c.**—It has been found that certain mineral substances influence in a remarkable degree the aspect and properties of bread, causing that made of inferior flour to resemble, in appearance, bread made from the best quality. Common salt produces this effect in a decided degree. It whitens the bread and causes it to absorb and retain a larger amount of water than the flour would otherwise hold. In consequence of this influence and under cover of the fact, that salt is a generally admitted element of diet, it is often introduced into bread more freely than is consistent with health (697). Alum has exactly the same effect on bread as common salt, but in a much more marked degree. A small quantity of it will bring up a bad flour to the whiteness of the best sort, and will enable it to hold an extra dose of water. It is much used for this purpose, and the baker who employs it not only practises upon the consumer a double imposition, but drugs him with a highly injurious mineral into the bargain. MITCHELL detected in ten four-pound loaves 819 grains of alum, the quantity in each loaf ranging from 34 to 116 grains. *Sulphate of copper* (blue vitriol), in exceedingly minute proportions, exerts a striking influence upon bread in the same manner as alum. *Carbonate of magnesia* has a similar effect, and its use in so large quantities as from 20 to 40 grains to the pound of flour has been recommended on scientific authority.* This substance has been also

* DR. C. DAVY.

recommended for correcting acidity in yeast, dough, &c., instead of soda, and because it is less powerfully alkaline. But from its difficultly soluble earthy nature, it tends to accumulate in the system in the highly objectionable shape of concretions and deposits.

522. **Liebig recommends Lime-water in Bread.**—However it is to be lamented, it is nevertheless a fact, that enormous quantities of flour, more or less deteriorated, are purchased in the markets of this country; and if there be any method of improving its condition by means that are not essentially injurious, they are certainly most desirable. Indeed, it is well known that flour is injured by *time* alone, so that freshly ground flower is always more prized than that which is several months old. The scientific reason is apparent. Vegetable gluten in contact with water becomes chemically changed, and loses its peculiar tough elastic properties. As these are essential to bread-making, flour that has been altered in this way necessarily makes a bad dough. Now, flour is in a high degree a water-absorbing substance, so much so that it attracts and combines with the moisture of the air, and is thus injured. This can only be avoided by artificial drying and protecting thoroughly from the air. The effect of the substances noticed in the previous paragraph is to combine with the gluten thus partially changed, and in a measure to restore its lost properties. Upon investigating this subject, Liebig found that *lime-water* is capable of producing this effect, and thus of greatly improving old, or low grade flour.

523. **How Lime-water Bread is prepared.**—To make lime-water chemists usually employ water that has been *distilled;* very pure soft water, as clean rain water, may, however, be used: Mix a quarter of a pound of slacked lime in a gallon of such cold water in stoppered bottles or vessels kept tight from the air. The mass of the lime falls to the bottom, leaving the liquid above, which has dissolved 1-600th its weight of lime, clear and transparent. This is to be poured off when required for use and replaced by pure water. Liebig recommends 5 lbs. or pints of lime-water to every 19 lbs. of flour, although this quantity of lime-water does not suffice for mixing the bread, and of course common water must be added, as much as is requisite. "If the lime-water be mixed with flour intended for the dough, and then the yeast added, fermentation progresses in the same manner as in the absence of lime-water. If at the proper time more flour be added to the risen or fermented dough, and the whole formed into loaves and baked as usual, a sweet, beautiful, fine-grained elastic bread is obtained of exquisite taste, which is preferred by all who have

eaten it for any length of time to any other."—(LIEBIG.) The use of lime-water removes all acidity from the dough, and also somewhat augments the proportion of water absorbed.

524. **Its Physiological claims.**—The quantity of lime introduced into the system by the use of this bread, is by no means large. A pound of lime-water suffices for 4 lbs. of flour, which with the common water added, yields 6 lbs. of bread; and as the pound of lime-water contains but 1-600th of lime, with this artificially added the cereal grains still contain less of it than peas and beans. Indeed, LIEBIG has suggested that experience may yet prove the cereal grains to be incapable of perfect nutrition, on account of their small proportion of the bone forming element.

525. **Different kinds of Bread.**—Rice flour added to wheaten flour enables it to take up an increased quantity of water. Boiled and mashed potatoes mixed with the dough cause the bread to retain moisture, and prevent it from drying and crumbling. *Rye* makes a dark-colored bread, and is capable of being fermented and raised in the same manner as wheat. It retains its freshness and moisture longer than wheat. An admixture of rye flour, with that of wheat, decidedly improves the latter in this respect. *Indian corn* bread is much used in this country. Mixed with wheat and rye, a dough is produced capable of fermentation, but pure maize meal cannot be fermented so as to form a light bread. Its gluten lacks the tenacious quality necessary to produce the regular cell-structure. It is most commonly used in the form of cakes, made to a certain degree light by eggs or sour milk and saleratus, and is generally eaten warm. Indian corn is ground into meal of various degrees of coarseness, but is never made so fine as wheaten flour. Bread or cakes from maize require a considerably longer time to be acted upon by heat in the baking process than wheat or rye. If ground wheat be unbolted, that is, if its bran be not separated, wheat *meal* or *Graham flour* results, from which *Graham* or dyspepsia bread is produced. It is made in the same general way as other wheaten bread, but requires a little peculiar management. Upon this point Mr. GRAHAM remarks: "The wheat meal, and especially if it is ground coarsely, swells considerably in the dough, and therefore the dough should not at first be made quite so stiff as that made of superfine flour; and when it is raised, if it is found too soft to mould well, a little more meal may be added." It should be remarked that dough made of wheat meal will take on the acetous fermentation, or become sour sooner than that made of fine flour. It requires a hotter oven, and to be baked longer. Puddings

in which flour is an ingredient are changed by the baking process in the same way as bread. They are usually mixed with milk instead of water, and made thinner than dough. Yeast is not used to raise them, eggs being commonly employed for this purpose, and sometimes other substances.

526. **White and Brown Bread—A new French Plan.**—M. Mouries, of Paris, has announced some new views of bread making, theoretic and practical, upon which a commission of the French Academy has just reported favorably. He claims the discovery of a nitrogenous substance called *cerealine*, which is a very active ferment, rendering starch soluble, altering gluten to a brown substance, and actively producing lactic acid instead of carbonic acid and alcohol. It resides near the surface of the wheat-grain, so that in grinding, it is nearly all separated in the bran, leaving but little in the white flour. M. Mouries states that in bread made from unbolted flour, the tendency to sourness, the softness, crumbliness, and want of firmness of the crumb, *and the brown color also* of the bread, are due to *cerealine.* He says cerealine ferment will make a brown bread of the whitest flour, whereas, if it be neutralized, a *white bread can be made from a dark flour containing bran.* He grinds wheat so as to separate it into about 74 per cent. of fine flour, 16 of brown meal, and 10 of bran. The brown meal is then so acted on by yeast as to neutralize the cerealine. The product in a liquid form is used to mix white flour into dough, which is baked as usual. The claims of this method are, a larger economy of ground products, making a white bread from dark materials, preventing the liability to acidity, and a yield of the finest, lightest, and sweetest bread, comprising the largest portion of farinaceous materials.

7.—Vegetable Foods changed by Boiling.

527. **Its General Effects.**—Boiling differs from baking in several respects. *First*, the heat never rises above the boiling point, and the changes of course are such only as may be produced by that temperature. *Second*, the food is surrounded by a powerful solvent, which more or less completely extracts certain constituents of the food. Vegetable acids, sugar, gum existing in the organic matter, and gum formed from starch, with vegetable albumen, are all soluble in water, and by boiling are partially removed. The tougher parts are made tender, the hard parts softened, and the connections of the fibres and tissues loosened, so as to be more readily masticated, more easily penetrated by the saliva and juices of the stomach, and hence more

promptly and perfectly digested. Perhaps we may here most conveniently consider the specific effects of heat upon the chief constituents of which vegetable foods are composed.

528. **Changes of Woody Fibre.**—A constituent more or less abundant of all vegetable substances is woody fibre. We find it in the husk or bran of grains, the membrane covering beans and peas, the vessels of leaves and leaf-stalks, the skin of potatoes, the peel and core of apples and pears, the kernels of nuts, and the peel of cucumbers, melons, &c., &c. We are hardly justified in ranking woody fibre, as PEREIRA has done, among aliments. Indeed, he remarks, "although I have placed ligneous matter among the alimentary principles, yet I confess I am by no means satisfied that it is capable of yielding nutriment to man." Yet it is important to understand how it may be affected by the heat of culinary operations. Boiling in water does not dissolve it; but by dissolving various substances with which it is associated, it only renders it the more pure. Yet woody fibre seems capable, by the joint action of heat and chemical agencies, of being converted into nutritive matter. If old linen or cotton rags, paper, or fine sawdust, be boiled in a strong solution of alkali, or moistened with pretty strong sulphuric acid, the woody substance is changed, being converted first into gum or dextrin, and then into grape sugar. By such modes of treatment old rags may be made to yield more than their weight of sugar. But *weak* solutions of acid or alkali do not produce any such effect. Nor will strong vinegar. We may therefore assume that woody fibre remains totally unchanged by exposure to culinary agencies and operations. Professor AUTENRIETH, of Tubingen, announced some years since, a method of preparing bread from wood-powder or wood-flour, which was changed into nutritive matter by successive heatings in an oven. We are not aware that his experiments have been confirmed, while it is suspected that whatever nutritive value his bread may have possessed, was due to starch associated with the wood.

529. **Changes of Sugar.**—Sugar, dissolved in cold water, or boiled to a sirup, has very different properties, as is well known to those who feed it to bees in winter. In the first case, the warmth of the hive will dry up the water and leave the sugar in hard crystals which the bees cannot take; but by boiling, the water and sugar become so intimately united that the mixture does not become dry, but retains the consistence of sirup. If melted sugar be kept for some time at 350°, it loses the property of crystallizing when redissolved in water, its properties being in some way deeply altered. If dry sugar be heated to a little above 400°, it loses the sugar taste and becomes not

only very soluble in water, but also very absorbent of it (*deliquescent*), turns of a deep brown color, and is used to stain liquids of a dark red, or wine color, under the name of *caramel.* Sugar itself is slightly acid, and forms compounds with bases which are of a salt nature, and known as *saccharates.* Caramel is more decidedly acid, and if the sugar be heated still higher it is converted into still stronger acid products with inflammable gases.

530. **Breaking up of the Starch Grains.**—The structure of starch grains has been described (384). They consist of layers or coats arranged concentrically around a point called the *hilum.* If one of these grains be strongly compressed between two plates of glass it breaks apart into several pieces, as seen in Fig. 100, and all the planes of rupture generally pass through the hilum as if the substance were less resistent at that point. But under the joint action of heat and water, the grains break up differently. Their membranes are torn apart, or exfoliated by internal swelling, as shown in Fig. 101.

FIG. 100.

Starch grain cracked through its hilum.

531. **Changes of Starch.**—Starch is but slightly acted upon by cold water. When heated with water it does not dissolve; but the grains swell, forming a viscid mucilaginous mass, a kind of stiff, half opaque jelly. When starch is diluted with twelve or fifteen times its weight of water, the temperature of which is slowly raised, all the grains burst on approaching the boiling point, and swell to such a degree as to occupy nearly the whole volume of the liquid, forming a gelatinous paste. If a pint of hot water be poured on a tablespoonful of arrow-root starch, it immediately loses its whitenes and opacity, becomes transparent, and the entire matter passes into the condition of a thick jelly. If a little of this be diffused through cold water and examined with the microscope, it will be seen that the starch grains are greatly altered. They have increased to twenty or thirty times their original size; the concentric lines are obliterated (384); the membrane of the grain is ruptured, and its interior matter has escaped. A cold jelly of starch and water, left to stand, either closed or exposed to the air, gradually changes, first into gum (dextrin), and then into sugar. The process, however, is slow, and months must elapse before the whole of the starch is thus transformed.

FIG. 101.

Starch grain ruptured by boiling.

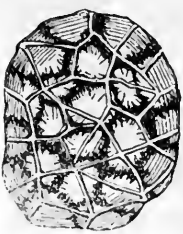
By being boiled in water for a considerable time, it undergoes the same change, and if the water be acidulous the change is quickened. When dry starch is gradually heated to a temperature not exceeding 300°, it slowly changes, acquires a yellow or brownish tint, and becomes entirely soluble in cold water. It is changed to dextrin or gum (British gum).

532. **How Potatoes are changed by Cooking.**—By referring to the statement of the composition of potatoes (461), we shall notice that a pound contains about three-quarters of a pound of watery juice, to two ounces, or two and a half, of starch. When examined by the microscope, the tissue of the potato is found to consist of a mass of cells, containing starch grains. Each cell contains some 10 or 12 grains, loosely situated, as shown in Fig. 102, and surrounded by the potato juice, which contains albumen. If potatoes be of good quality, they boil dry, or *mealy*, as it is termed. But their water or juice does not separate, or boil out. It is absorbed by the starch grains, which form a compound with it, and swell up so as completely to fill, and even burst the cells, as seen in Fig. 103. The albumen at the same time coagulates, so as to form irregular fibres, which are seen among the starch grains. When the juice of the potato is only partially absorbed by the starch, it is said to be watery, waxy, or doughy. Potatoes by boiling in water do not form a jelly, like common starch, because the starch grains in the tubers are protected, partly by the coats of the cells in which they are contained, and partly by the coagulated albumen. "Potatoes steamed or roasted—or if boiled, mashed so as to extract all hard lumps, are in the best condition for digestion. Frying them, toasting them, baking them, or browning the surface, dries up the starch into a hard, half-charcoally mass, which, except in most powerful stomachs, must act as a foreign body."

Fig. 102.

Starch grains of potato before boiling.

Fig. 103.



Starch grains of potato after boiling.

533. **Quality of the Water for Culinary Purposes.**—Soft water, or that which is free from dissolved mineral matter, makes its way into, or is imbibed by organized tissues, with much more readiness and facility than hard water. It also exerts a more powerful solvent or extractive action, and thus is a better vehicle for conveying alimentary sub-

stances into the living system. In culinary operations where the object is to soften the texture of animal and vegetable matter, or to extract from it and present in a liquid form some of its valuable parts, as in making soups, broths, stews, or infusions, as of tea or coffee, soft water is the best. But there are cases in which the solvent action of soft water is too great, as sometimes upon green vegetables, which it makes too tender, destroying the firmness that is essential to the preservation of their juices, which are dissolved and extracted, making the substance proportionately tasteless. In those cases, therefore, when we do not desire to dissolve out the contents of a structure, but to preserve it firm and entire, hard water is better than soft. To prevent this over-dissolving action, common salt is often added to soft water, which hardens it. This fact also explains why it is impossible to correct and restore the flavor in vegetables that have been boiled in soft water by afterwards salting them. It is well known that peas and beans do not boil soft in hard water. This is owing to the effect which salts of lime, especially the sulphate or gypsum, exert in hardening or coagulating casein which abounds in these seeds. Onions furnish a good example of the influence of *quality* in water. If boiled in pure soft water, they are almost entirely destitute of taste; though when cooked in salted water, they possess in addition to the pleasant saline taste, a peculiar sweetness, and a strong aroma; and they also contain more soluble matter than when cooked in pure water. The salt hinders the solution and evaporation of the soluble and flavoring principles.

8. How Cooking changes Meat.

534. **Action of Heat upon the Constituents of Flesh..**—If the pure fibrin of meat is exposed to a moderate heat, it parts with a large portion of its water, which it held like a sponge, and loses the power of taking it up again. It consequently shrivels and shrinks. If the heat be carried high, further decomposition and charring take place. The effect of boiling upon fibrin, is not to make it more tender, but to increase its hardness and toughness. A low degree of heat changes liquid *albumen* to the solid condition; altering remarkably all its physical properties. It neither dissolves in water, hot nor cold, and is impenetrable to it. If diffused through one or two hundred times its weight of water, it coagulates, forming fine fibrous meshes throughout the liquid sufficient to entangle any mechanical substances that may be floating in it, and bring them to the surface or carry them to the bottom. In this way albumen is used as a clarifying agent. If its proportion be much

larger, the entire water may combine with it and pass into the solid state. The egg, for example, contains 74 per cent. of water and 10 of oil, yet its contents are all solidified by boiling through the action of 14 per cent. of pure albumen. *Fat* is liquefied, of course, by the action of heat, and at a high temperature it is resolved into various acid and acrid bodies. The effect of heat upon flesh in the mass, has been investigated by LIEBIG, with his usual acuteness and with highly interesting and practical results.

535. **Properties of the Liquid and Solid parts of Flesh.**—When muscular flesh or lean meat is chopped fine, and steeped or leached with cold water, there remains a solid residue consisting of the muscular fibres, tissues, vessels, &c. If this be boiled, it is tasteless, or indeed slightly nauseating; it cannot be masticated, and even dogs reject it. All the savory constituents of the flesh were contained in its juice; and were entirely removed by cold water. The watery infusion thus obtained, is tinged red by some of the coloring matter of the blood. If it be boiled, this coloring matter separates, leaving the liquid clear and of a pale yellowish color. This liquid has the aromatic taste, and all the properties of soup made by boiling the flesh. When evaporated and dried, a soft brown mass amounting to 12 or 15 per cent. of the weight of the original *dry* flesh is obtained, having an intense flavor of roast meat. This extract of flesh is soluble in cold water, and when dissolved in about 32 parts of hot water, with salt, it gives to this water the taste and all the properties of an excellent soup. The liquid extract retains the peculiar taste of the flesh from which it was derived; so that if we add the concentrated juice of venison or fowl to exhausted beef, the latter at once acquires a venison or fowl taste.

536. **Loss of Weight in Cooking.**—The first effect of applying a strong heat to a piece of fresh meat, is to cause the fibres to contract, to squeeze out a portion of the juice, and partially to close the pores so as to prevent the escape of more. Heat is applied to meats chiefly in three ways, *boiling*, *roasting*, and *baking*. During these operations, fresh beef and mutton, when moderately fat, lose on an average about as follows:

	In boiling.	In baking.	In roasting.
4 lbs. of beef lose	1 lb.	1 lb. 3 ozs.	1 lb. 5 ozs.
4 lbs. of mutton lose	14 ozs.	1 lb. 4 ozs.	1 lb. 6 ozs.

The greater loss in baking and roasting, arises chiefly from the greater quantity of water evaporated, and of fat which is melted out during these two methods of cooking.

537. **Best method of cooking Meat.**—In preparing meat for the table,

we shall discover it to be most desirable that the ingredients of its juice should remain in it; and this will depend much upon the method of culinary procedure. If the piece of meat be introduced into the water *when briskly boiling*, the albumen at its surface, and to a certain depth inward, is immediately coagulated; thus enclosing the mass in a crust or shell which neither permits its juice to flow out, nor the external water to penetrate within, to dissolve, dilute, and weaken it. The greater part of the sapid constituents of the meat are thus retained, rendering it juicy and well-flavored. It should be boiled for only a few minutes, and then kept for some time at a temperature from 158° to 165°. Meat is under-done or bloody, when it has been heated throughout only to the temperature of coagulating albumen (140°); it is quite done or cooked, when it has been heated through its whole mass to 158° or 165°, at which temperature the coloring matter of the blood coagulates. As in boiling, so in baking or roasting; for whether the meat be surrounded by water, or in an oven, as soon as the water-proof coating is formed around it, the further changes are effected alike in both cases, by internal vapor or steam. In roasting or baking, therefore, the fire should be at first made quite hot, until the surface pores are completely plugged, and the albuminous crust formed. Hence, a beef-steak, or mutton-chop, is done quickly over a smart fire that the richly-flavored natural juices may be retained.

539. **Objection to the common method.**—The fibrin of meat, in its natural state, is surrounded by an albuminous liquid. In coagulating, it becomes firm and hard, but at the same time, brittle and tender. If the albumen be coagulated within the meat, it forms a protective sheath around the fibres, and thus prevents them from being shrivelled, toughened, and hardened by boiling. This explains why the flesh of young animals, which is richer in albumen than that of old ones, is also more tender. If the meat be placed in cold water, and the temperature slowly raised to boiling, a portion of the savory and nutritive juices is dissolved out, and the meat becomes proportionally poorer for the loss. At the same time the fibres lose more or less of their shortness, or tenderness, and become tough. The smaller or thinner the piece of flesh is, the greater is its loss of savory constituents. If, in baking, the meat be exposed to a slow fire, its pores remain open, there is a constant escape of juice from within, and the flesh becomes dry and unsavory.*

* The flesh of old animals often yields no more than 1 or 2 per cent. of albumen, that of young animals as much as 14 per cent.—Liebig.

540. **Soup, Beef-tea, Mutton-broth, &c.**—In the preparation of these our object is the reverse of that which has just been considered. We desire to take the nutritive and savory principles *out* of the meat, and get them into a liquid or soluble form. To obtain a liquid extract of meat, in the form of soup, broth, or tea, the flesh is finely chopped and placed in *cold water*, which is then slowly heated and kept boiling for a few minutes, when it is strained and pressed. In this manner we obtain the very strongest and best flavored soup which can be made from flesh. "When one pound of lean beef, free of fat, and separated from the bones, in the finely-divided state in which it is used for beef-sausages or mince-meat, is uniformly mixed with its own weight of cold water, slowly heated to boiling, and the liquid after boiling briskly for a minute or two is strained through a towel from the coagulated albumen and fibrin, now become hard and horny, we obtain an equal weight of the most aromatic soup of such strength as cannot be obtained, even by boiling for hours, from a piece of flesh."—(LIEBIG.) To make the best article, it is desirable not to boil it long, as the effect is to coagulate and render insoluble that which was extracted by cold water, and which should have remained *dissolved* in the soup. It is obvious from what has been said, that a piece of meat introduced undivided into boiling water, is in the most unfavorable condition possible for making good soup. It is customary in soup-making to protract the boiling for the purpose of thickening and apparently enriching the soup. This is effected by the gelatin, which is gradually extracted from the tissues, bones, and other parts, but in a nutritive point of view this ingredient is a fiction, as will be shown in the proper place (717). Soup-making is a kind of analysis of alimentary substances used in its preparation—a part is taken, and a residue usually rejected. Yet it is clear that we shall have the *completest* nourishment by taking both parts, as the fibre of meat and the softened beans and peas of their respective soups.

541. **A new Broth for Strengthening the Sick.**—In certain maladies (as typhus fever, for example, at particular stages), the greatest difficulty met with by the physician, lies in incomplete digestion, or inability promptly to reinforce the exhausted and bankrupt blood. To meet this difficulty LIEBIG prepared, as follows, a nutritive liquid, which has been used at Munich with the best results. Take half a lb. of *perfectly fresh* meat (beef or chicken), cut it in small pieces, add to it $1\frac{1}{8}$ lb. of distilled (pure soft) water, with four drops of muriatic acid, and half a drachm of common salt; mix the whole well together, and after standing an hour, strain through a common hair sieve, letting it pass

without pressing or squeezing. The portion passing through first being cloudy, it is again poured through the sieve, and this process is repeated until it becomes perfectly clear. Upon the residue of meat remaining in the sieve, half a pound of distilled water is poured in small portions. In this manner a pound of cold extract of meat is obtained, of a red color, and pleasant meat-broth taste. It must not be heated, and is administered cold, by the cupful, according to the patient's inclination. It is difficult to make it in summer, on account of its liability to ferment and change. Perfectly cold water must be used, and refrigeration with ice will guard against decomposition.

9. Preparation and Properties of Butter.

542. **Action of Heat upon Milk and Cream.**—The gradual heating of milk facilitates the rising of its cream. The oil globules are broken, liquefied, run together, and ascend to the upper part of the vessel. There is always a trace of albumen in milk; when boiled this is coagulated and rises to the surface with oil globules, and forms there a pelicle or skin, which is increased by evaporation. The layer thus formed prevents the escape of steam, causing the liquid to boil over if the vessel is not removed from the fire. If cream be heated for some time nearly to boiling, its fat-globules melt together and collect upon the surface, as a fluid oil. When this is cooled it forms a very pure butter, which will keep long without being salted or becoming rancid, but has neither the fine flavor nor the firm consistence of churned butter.

543. **Butter separated mechanically.**—If either milk or cream be beaten or agitated mechanically for a time, the oil globules coalesce and form a mass of butter. It is believed that each little fat-globe is enclosed in a thin film of casein, which is ruptured by agitation. However this may be, the oil-cells have sufficient resistance to require considerable mechanical violence to break them up, which is effected by churning. During this operation oxygen is absorbed from the air, the temperature rises, the cream or milk, if not already acid, turns sour, and gases are set free, which escape from under the cover, or when the churn is opened.

544. **Rate of Motion in Churning.**—In churning cream, which is usually thick and uneven, the agitation should at first be slow, until it has become completely broken into a uniform mass. As it becomes thinner the motion is easier and may be slightly increased, and continued until a change in the sound from a low and smooth to a harsh tone is

observed. It may then be again slightly increased, until the butter begins to form, when it is collected or 'gathered' by a slower movement. If the rate of motion in churning is too rapid, the cream is liable, especially at high temperatures, or in hot weather, to *burst*, as it is called, while the butter is soft, frothy and bad.

545. **Time and Temperature.**—With different churns, and at different rates of speed, butter may be produced in from 10 minutes to 3 or even 5 hours. Dr. MUSPRATT assigns from 45 minutes to an hour as the best time for cream, while Prof. AYTON states for cream an hour and a half, and for whole milk from two to three hours. DICKENSON says it is no matter if we are six hours in churning sweet milk. It is, however, the well established result of experiment, that the more quickly milk or cream is churned, the paler, softer, and poorer is the butter. It is said also that in over-churning, that is, when the operation is too long continued after the butter is produced, it is apt to be softened and lightened in color, although the quantity may be somewhat increased. We have had frequent occasion to notice the controlling influence of temperature over the changes of matter, and we find it again illustrated here. Cream, when put into the churn, should never be warmer than 53° to 55°. It rises during churning from 4° to 10°. JOHNSTON states that when the whole milk is churned, it should be raised to 65°. The careful regulation of the temperature is of the first importance, so that a thermometer is indispensable to the proper management of the operation. Some churns have them attached, which is an excellent plan. The temperature of the cream is increased or diminished by mixing with hot or cold water, but many strenuously object to this. In some churns there is an outer chamber or vessel, which is separated from the cream by a thin sheet of metal, through which heat or cold readily passes from water contained in the chamber. This is a good arrangement, although the metal commonly used (*zinc*) is not quite free from objection (611).

546. **Composition and properties of Butter.**—The mass of butter is a tasteless and inodorous fat; its pleasant aromatic flavor being due to a compound existing in it in very small quantity, namely, *butyric acid*, combined with *oxide* of *lipyle*. First quality butter has a pleasant peculiar aroma, is of a fine orange-yellow color, solid, and of a waxy or *grained* texture, exposing a different surface when cut from fat or grease. This granular quality results from the peculiar mode of its production, which is by the mechanical coherence of minute butter-particles or grains. Were butter separated like lard, by melting, it would not present this appearance. Between good ordinary butter

and a first-rate article there is a wide difference; the former is common, the latter is but rarely seen. Cream and butter are both highly absorbent of unpleasant odors, and are extremely susceptible of taint from this cause. The air of the dairy-house must be "sweet as that wafted from the rose itself. A common farm cellar with meat, fish, and vegetables, would spoil the best package of butter ever made in sixty days." The cows should be kept on rich, tender, high-flavored grasses,—timothy, white clover, blue grass, red-top, with which the ground is to be thickly swarded over to protect it from sun and drouth. May, June and September are the best months, July and August being too hot; while after frost appears, the grass becomes insipid and bitter, and will not yield butter of the best quality. Almost every kind of butter, however, is good when newly made. The vital considerations of its manufacture are connected with its quality of keeping, which will be noticed when we reach the subject of preservation (599).

10. Preparation and Properties of Cheese.

547. **Spontaneous Curdling of Milk.**—When milk is left to itself for a time, which is shorter in warm or stormy weather, it sours and curdles, that is, its *casein* changes from the dissolved to the solid state. This is brought about by a series of interesting and beautiful changes originating in the unceasing activity of atmospheric oxygen. Casein, in itself, is insoluble in water. But it is of an acid nature, and is capable of combining with potash or soda, and forming a compound which dissolves in water. Soda is the alkali which holds the casein of milk in solution. Now when fresh milk is exposed to the air, its oxygen acting upon a portion of the nitrogenous casein, changes it to a ferment; and this takes effect upon the milk sugar, converting it into lactic acid, which causes the sourness of milk. When sufficient of the lactic acid is thus formed, it seizes upon the soda, takes it away from the casein, and forms *lactate of soda.* The casein thus set free shrinks in bulk, and gathers into an insoluble, curdy mass, the operation being aided by a gentle warmth.

548. **Artificial Curdling with Acids.**—In making cheese the milk is curdled artificially, and in different countries various substances are used for this purpose. But they all produce the effect in precisely the same way, that is, an acid substance is employed to neutralize the soda of the milk, by which the casein assumes the coagulated state. Almost any acid will have the effect of curdling milk. Muriatic acid, weakened with water, vinegar, tartaric acid, cream of tartar, lemon juice, and sour milk, are each used for the purpose.

549. **Artificial Curdling with Rennet.**—The salted and dried stomach of the unweaned calf, lamb, or pig, is called *rennet*. If a small piece of this be soaked in water for a time, and the infusion be mixed with milk at a temperature of 90° or 95°, curdling shortly takes place. It was once supposed that it is the acid of the gastric juice of the stomach which produces the change; but this cannot be, as the membrane acts with equal promptitude, though it has been thoroughly washed free from every thing of an acid nature. The change is due to the action of the animal matter itself. It is said that the rennet should never be used unless ten or twelve months old. During this period, by exposure to the air, a portion of the membrane has undergone decay and become soluble in water. This decomposing animal matter acts upon the sugar of milk, changing it to lactic acid, which produces curdling exactly as in spontaneous coagulation (547). There is much about the action of rennet that is not yet explained. Its condition seems to exert a decided influence on the quality of the cheese. The result is probably much influenced by the *state of decay* of the animal matter, as the decomposition may be so far advanced as to induce putrefaction in the milk.

550. **Conditions of the preparation of Cheese.**—By the action of curdling agents the milk is divided into two parts; first the *curd*, comprising all the casein, a large portion of oil and a trace of sugar of milk, with some water; and second, the *whey* or fluid part containing the bulk of water, the sugar of milk, and a small but variable proportion of oily matter. Of the saline matter in milk, the phosphates of lime and magnesia exist in the curd, while the remaining salts are found in the whey. The curd, separated from the whey and prepared in various ways, and then pressed, forms *cheese*. The properties of cheese are influenced by a great number of circumstances. Pure casein makes a cheese poor, hard, and horny. The admixture of the oil or cream of the milk enriches it in proportion to its quantity. The most inferior cheeses therefore are made from milk that has been repeatedly skimmed and deprived of all its oil, while the richest cheeses are those made directly from cream (cream cheeses), and which hence contain an excess of oily matter. Between these extremities there are all grades of quality, which depend upon the *proportion* of the constituents. Thus if we use the new milk of the morning, mixed with the previous evening's milk that has been deprived of its cream, we get a cheese of a certain quality; if we use the *whole milk* of the previous night, the cheese will of course be better; and if we use only the *cream* of the previous evening's milk, the cheese will be still

richer. All the conditions which influence the properties of the milk itself (334) affect also the quality of the cheese. The heat, in curdling, should not be too high, as it is apt to give excessive oiliness to the fatty portion of the milk. A thermometer affords more reliable indications than the sense of feeling. As soon as coagulation is complete, the curd should be separated, as the longer it stands the harder and tougher it is. Much judgment is required to know the proper quantity of rennet to be used; if there is too little, the process is too slow, and time is given for the butter to separate itself from the curd, while too much rennet makes the curd tough, and otherwise affects disagreeably the subsequent changes and flavor of the cheese. The mode of separating the curd from the whey, its subsequent preparation, and the degree and duration of the pressure applied, together with a great variety of other circumstances known to the skilful cheese-maker, have a powerful influence upon the quality of the article produced. We shall refer to cheese again when speaking of preservation (604).

IV.—COMMON BEVERAGES.

1. Properties and Preparation of Tea.

551. **The Tea Shrub.**—Tea consists of the prepared leaves of the tea-plant, a hardy shrub which grows from 3 to 6 feet high, chiefly in China. The plant is propagated from the seed, and matures in from two to three years, yielding usually three crops of leaves each season. When a year old, the young bushes are planted out in rows 3 or 4 feet apart, and being cropped down so as to grow thick and bushy, the tea-field resembles a garden of gooseberry bushes. The leaves are picked by hand in May and June, and the plant yields leaves from four to six seasons.

552. **What causes different varieties of Tea.**—Many varieties of tea of all grades of quality are known in market. These differences depend *first* upon the soil, climate, culture, &c., of the locality where it is grown. *Second*, upon the time of picking; the young unexpanded leaves that are gathered first being tender and delicate, while the second and third gatherings are more bitter, tough, and woody. *Third*, the mode of treatment or preparation, which consists in drying, roasting, and rolling in the hand, by which the leaves acquire their twisted appearance, and finally sifting and winnowing. The methods of handling are various, and much depends upon them.

553. **Difference between Green and Black Teas.**—All the different varieties of tea are classed as either *green* or *black*. What constitutes

the real difference between these two sorts has long been a matter of doubt. It was at first supposed that they came from totally different species of plants; but the latest accounts agree that they are both derived from the same plant, the difference being in conditions of growth and modes of dealing with the leaves. They may be thus contrasted:

GREEN TEA.

1. Cultivated in manured soils.

2. Leaves are steamed, withered and roasted almost immediately after gathering.

3. They are dried quickly after the rolling process; the whole operation being brief and simple.

BLACK TEA.

1. Grown chiefly on the slopes of hills and ledges of mountains.

2. Allowed to be spread out in the air for some time after they are gathered.

3. They are tossed about until they become soft and flaccid.

4. They are now roasted for a few minutes, and rolled.

5. They are exposed to the air for a few hours in a soft moist state.

6. Lastly, they are dried slowly over charcoal fires.

It is by lengthened exposure to the air in the process of drying, accompanied perhaps by a slight heating and fermentation that the dark color and distinguishing flavor are given to the black teas of commerce. The oxygen of the atmosphere acts rapidly upon the juice of the leaf during this exposure, and changes chemically the peculiar substances they contain, so as to impart to the entire leaf the dark hue it finally acquires. The precise nature of these changes has not been chemically investigated.—(JOHNSTON.) The unchanging green color of green teas is produced, says KNAPP, by employing steam to wither the fresh leaves, it being well known to collectors of plants, that many which inevitably turn black when simply dried, preserve their green color brilliant and permanent, when they are killed by steam, previously to drying. The same authority remarks, that green tea gives up much less of its juice in the drying process; a circumstance which fully explains its more energetic action upon the nervous system.

554. **Varieties of Green and Black Tea.**—The most important teas of commerce may be thus arranged, beginning with the lowest qualities. Annexed is an approximative scale of the prices per pound paid for them in Canton.

Green Teas.		Black Teas.	
Twangay	18 to 27 cts.	Bohea	12 to 18 cts.
Hyson Skin	18 to 30 "	Congou	22 to 25 "
Young Hyson	27 to 40 "	Campoi	22 to 30 "
Hyson	40 to 56 "	Souchong	20 to 35 "
Imperial	45 to 58 "	Caper	20 to 40 "
Gunpowder	45 to 60 "	Pekoe	35 to 75 "

Twangay is the coarsest and most inferior of the green teas. The *Hysons* are of a better quality, and are more widely used. The word ' Hyson ' is derived from Hee-chun, the name of a celebrated Chinese tea-maker. *Hyson-skin* is composed of the light, inferior leaves, separated from Hyson by winnowing. *Young-Hyson*, *Hyson*, and *Imperial*, consist of the second and third crops; while *Gunpowder*, the finest of the green teas, consists of the first leaves, or leaf-buds, of the vernal crop. It is called 'gunpowder,' from the fancied resemblance of its small rounded leaves to gunpowder grains. *Bohea* is the poorest and cheapest of the black teas, and takes its name from being largely produced on the Bohea mountains; *Congou*, from cong-fou, ' made with care,' and *Souchong*, from se-ou-chong, "a very little sort," are better varieties. *Caper* comes in little balls or grains, made up in the form of capers. *Pekoe* is the best of all the black teas, and corresponds to gunpowder among green teas. The word 'Pekoe,' or Pak-Ho, means ' white down,' and is applied to the first downy leaves of the spring growth. It is often called the *Flowery Pekoe*, which is erroneously supposed to refer to the blossom of the tea-plant; but the tea flower itself has little fragrance, and although sometimes used in China, is not imported.

555. **Composition of Tea.**—The analysis of tea shows it to be composed of four principal constituents. *First*, an aromatic, volatile oil, which produces the peculiar odor and flavor. It is of a citron yellow color, floats on water, and when exposed to the air is quickly converted into a solid resin by atmospheric oxygen. It has such a powerful taste, that when placed on the tongue it spreads over the entire throat, and exerts a painful action upon the nerves. It does not exist in the fresh or natural leaves, but is produced during the roasting process. A hundred pounds of tea yield only a single pound of the oil. *Second*, tea contains a peculiar principle called *thein*, a substance rich in nitrogen, and classed among *vegetable alkalies*. STENHOUSE states that ordinary tea contains about two per cent. of thein; but PELIGOT has found as much as 6 per cent. in certain green teas, although this quantity is very unusual. Thein has a slightly bitter taste, no smell, and dissolves in hot water. An infusion of tea, therefore, contains dissolved thein: and if the leaves be of good quality, an ounce will yield about 10 grains. *Third*, *tannin* or *tannic acid*, a substance so named because it is the ingredient in oak and hemlock bark, which combines with leather in the operation of tanning. If a compound of iron (sulphate of iron—copperas, for example), be introduced into an infusion of tea, it turns it to an inky blackness, by precipitating its tannic acid.

This substance is a powerful astringent, and gives to tea its astringent taste and properties. It forms from 12 to 18 per cent. of the weight of tea. When tea is steeped, the three foregoing constituents are communicated to the water; they hence give its active properties to the ordinary beverage. But tea leaves contain, *fourthly*, another constituent, namely, *gluten*—which, not being dissolved by hot water, is usually lost with the dregs or grounds. The proportion of this substance is stated to be as high as 25 per cent., so that the leaves, after exhaustion by steeping, are still highly nutritive. In some localities it is customary to eat them.

556. **How Tea is best made.**—The Chinese method is to throw some tea into a cup, and pour boiling water over it; they cover the cup with a shallow saucer, and let it rest for some time. After it has stood sufficiently long, they pour the clear liquid into a saucer, and drink it hot. Various methods are pursued in different countries, but a knowledge of the composition and properties of tea is the best guide in preparing its infusion. It is desirable to obtain from the leaves the largest possible amount of matter which water will extract, and retain them in the liquid. The thein of tea is in combination with tannic acid, forming a compound which requires boiling water to dissolve it. But, on the other hand, the aromatic oil of tea is volatile, so that the boiling tends to drive it off with the steam into the air. If lukewarm water is used, the most important element of tea, its thein, is not obtained; while, by boiling, its fragrant aroma is wasted. The plan to be pursued, therefore, is to pour boiling water upon the tea, *in close vessels*, so that its active ingredients may be dissolved, and at the same time the volatile oil retained in the mixture. In cooling, a good decoction of tea becomes slightly turbid, the *tannate* of *thein* being no longer held in solution, is precipitated and rises, forming a skin upon the surface.

557. **What remains in the Grounds, or residue.**—If tea be steeped in water below the boiling temperature, an infusion is obtained, having the peculiar tea-taste, but the thein is not obtained; a second infusion of the leaves with boiling will extract the thein, and tannic acid, so that, although it may be less fragrant, it will be more active. The leaves which have been used of course vary in composition, according to the completeness of the first exhaustion. By the common method of extraction, the entire quantity of thein is never dissolved, about one-third being left in the leaves. MULDER found hot water to extract from six specimens of black tea, from 28 to 38 per cent. of their weight; of the same number of kinds of green tea, from 34 to 46 per

cent. Peligot procured from black tea an average of 38 per cent., and from green, 43 per cent. Yet the quantities are by no means constant, as different samples of the same color and name in the market yield very different proportions of soluble matter. Teas prepared from young leaves furnish more soluble matter than the older leaves; while green teas give more of light-colored, and black of dark-colored ingredients. The gluten, in which tea leaves are rich, is not dissolved by boiling water; but water made slightly alkaline dissolves gluten. It has therefore been recommended that a little soda be added to the water, which would have the effect of making the tea slightly more nutritious.

558. **Adulterations of Tea.**—Teas of all sorts are liable to the grossest adulterations. The green teas are extensively stained or painted by the Chinese, to heighten their green color. For this purpose they use Prussian blue, indigo, turmeric, gypsum, and China-clay. With these ingredients they glaze or face the surface of the leaves, to such an extent, that it is affirmed we *never* get pure green tea. Other leaves are also often mixed with those of the tea-plant, by the Chinese. In England, the leaves of the *sloe* and *thorn* are much mixed with tea. The Chinese also make a crude and worthless preparation of sweepings, dust, sand, leaves, and various impurities of the tea warehouses, cemented with gum or rice-water, which they honestly call *lie-tea*, and employ it extensively to mix with other teas. In England, exhausted leaves are bought up, their astringent property restored by the addition of *catachu* (a concentrated tanning extract), and colored with black lead, logwood, &c., are sold again as genuine tea. Another fraud of great prevalence consists in mixing inferior qualities of tea with the better sorts, and cheating the purchaser by selling the compound at the price of the best article. To detect indigo or Prussian blue in tea, let a portion of it be shaken with cold water and thrown upon a bit of thin muslin, the fine coloring matter will pass through the muslin, and settle to the bottom of the water. When the water is poured off, the blue matter may be treated with a solution of chloride of lime. If it is bleached, the coloring matter is indigo. If potash makes it brown, and afterwards a few drops of sulphuric acid make it blue again, it is Prussian blue.—(Johnston.)

2. Properties and Preparation of Coffee.

559. **The Coffee Tree and its Seeds.**—Coffee is the product of a plant, grown extensively in warm climates. The natural height of the tree,

varies from 10 to 30 feet; but it is usually pruned down to 5 or 6 feet, to increase the crop of fruit. All are familiar with the structure of coffee seeds; they are of an oblong figure, convex on one side, and flat, with a little straight furrow, on the other. They are enclosed in a pulpy berry of a red color, which resembles a cherry, and are situated within it with their flat sides together, and invested by a tough membrane called the *parchment.* The seeds are separated by fermenting the berries, crushing them under heavy rollers, drying, grinding, and winnowing.

560. **Varieties of Coffee.**—The best coffee is the Arabian; that grown in the province of Mocha (*Mocha coffee*) is of the finest quality. It may be known by having a smaller and rounder berry than any other, and likewise, a more agreeable smell and taste. It is of a dark yellow color. The *Java* and *East Indian* coffees are larger and of a paler yellow, while *Ceylon*, *West Indian*, and *Brazilian* coffees are of a bluish or greenish gray tint.

561. **Composition of Coffee.**—The raw coffee, as it comes to market, is but slightly aromatic; its odor is faint, while its taste is moderately bitter and astringent. In this state its composition, according to Payen, is as follows:

Water	12
Gum and Sugar	15·50
Gluten	13
Cafein	00·75
Fat and Volatile Oil	13
Tannic Acid	5
Woody Fibre	34
Ash	6·75

Dr. Stenhouse states that it contains 8 per cent. of cane sugar. Coffee, it will be seen, contains tannin, the same astringent principle as tea, but in much smaller proportion; and the substance itself is of a somewhat different chemical nature. They both contain much gluten; but the most remarkable point of similarity between tea and coffee, is found in the fact, that the *cafein* of coffee is a *vegetable alkali*, with the same composition and properties as thein of tea. A direct analysis of the two substances gave the following result:

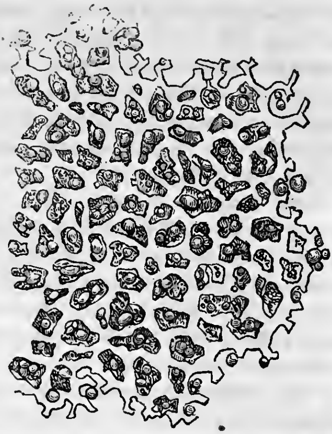
	Carbon.	Nitrogen.	Hydrogen.	Oxygen.
Thein	50·1	29·0	5·2	15·7
Cafein	49·8	28·8	5·1	16·2

The proportion of cafein in coffee is probably somewhat higher than the preceding analysis indicates. It is of course variable; but is about half that of thein in tea (555). Coffee, however, is not used

in the raw or natural state; like tea, it is first altered by heat or roasted.

562. **Effects of roasting Coffee.**—The operation of roasting, produces several important changes in coffee. In the first place, the raw coffee-berries are so tough and horny, that it is very difficult to grind, and pulverize them sufficiently fine, that water may exert its full solvent effect upon them. Roasting renders them yielding and brittle, so that they may be more readily ground; while, at the same time, it increases the amount of matter soluble in hot water. If we examine the raw coffee seed with the microscope, it will be found to consist of an assemblage of cells, in the cavities of which are seen small drops of the aromatic volatile oil of coffee. This appearance is shown in (Fig. 104). If now we place a fragment or section of roasted coffee under a magnifier, it will be observed that these drops of oil in the cells are no longer visible (Fig. 105). They have, in part, been dissipated by the heat, and in part, become more generally diffused throughout the mass of the seed; a portion being driven to the surface. It is obvious, that roasting produces certain chemical changes in coffee, which alter its flavor and taste, and bring out the peculiar and highly esteemed aroma for which this beverage is distinguished. Johnston states that the peculiar aromatic principle which gives flavor to coffee, exists in extremely minute quantity, (one part in fifty thousand,) and is generated in the roasting process. The heat also

Fig. 104.



Appearance of unroasted coffee-berries magnified, showing the size and form of the cells, and the drops of oil contained in their cavities.

Fig. 105.

Appearance of roasted coffee berries.

sets a portion of the cafein free from its combination with tannic acid, and evaporates it. The temperature is sufficiently high to decompose the sugar, and change it to brown, burnt sugar, or *caramel.* Coffee darkens in color during roasting, swells much in bulk, and loses a considerable portion of its weight, by evaporation of its water and loss of other constituents. Coffee roasted to a *reddish brown*, loses in weight, 15 per cent., and gains in bulk, 30 per cent. To a *chestnut brown*, it loses 20 per cent. in weight, and gains 50 in bulk. To a *dark brown*, it loses 25 per cent. of weight, and gains 50 in bulk.

563. **Hints concerning the Roasting Process.**—The roasting of coffee is an operation of considerable nicety; more, perhaps, depending upon it than upon the variety of the article itself. Coffee is roasted by the dealers, in hollow iron cylinders or globes, which are kept revolving over a fire. As the first effect is the evaporation of a considerable amount of water, if the vessel be close this is retained, and the coffee roasted in an atmosphere of its own steam. This is not thought to be the best plan, and if the operation be carried on at home, it is recommended that the coffee be first dried in an open pan over a gentle fire, until it becomes yellow. It should then be scorched in a covered vessel, to prevent the escape of the aroma; taking care, by proper agitation, to prevent any portion from being burnt; as a few charred grains communicate a bad odor to the rest. It is important that just the right temperature should be attained and kept. If the heat be too low, the aromatic flavor is not fully produced, and if it be too high, the rich oily matter is dissipated, leaving only the bitterness and astringency of the charred seeds. The operation should be continued until the coffee acquires a deep cinnamon or chestnut color, and an oily appearance, and the peculiar fragrance of the roasted coffee is sufficiently strong. It may then be taken from the fire, and allowed to cool without exposure to the air, that the aromatic vapor may condense and be retained by the roasted grains. Coffee is very apt to be over-roasted, and even a slight excess of heat greatly injures its properties.

564. **Effects of Time upon Coffee.**—Coffee berries undergo a change called *ripening*, by keeping; that is, they improve in flavor. The Arabian coffee ripens in three years, and it is said that in ten or a dozen years the inferior American coffees become as good, and acquire as high a flavor as any brought from Turkey.—(Ellis.) But it is different after the coffee is roasted and ground. Its flavoring ingredients have a tendency to escape, and it should therefore be confined in ves-

sels closed from the air. It should not be exposed to foreign or disagreeable odors, as it has a power of imbibing bad exhalations, by which it is often injured. Many cargoes of coffee have been spoiled from having been shipped with, or even put into vessels which had previously been freighted with sugar. A few bags of pepper are sufficient to spoil a whole ship-load of coffee.—(NORMANDY.)

565. **Mode of Preparing the Beverage.**—To prepare the coffee, it should be roasted and ground just before using, no more being ground at a time than is wanted immediately. Of course the finer it is reduced the stronger will be the extract from a given weight of coffee, one-fourth more soluble matter being obtained from coffee ground to the fineness of flour than from the ordinary coarse powder (KNAPP). If a cup of good coffee be placed upon a table, boiling hot, it will fill the room with its fragrance. Its most valuable portion is thus liable to be exhaled and lost. Hence the same difficulty is encountered as in tea making; boiling dissipates the much-prized aroma; but a high heat is necessary to extract the other important ingredients of the coffee. It should therefore be *steeped* rather than boiled, an infusion, and not a decoction being made. Some make it a rule not to suffer the coffee to boil, but only to bring it just to the boiling point. Yet, a few minutes' boiling undoubtedly increases the quantity of the dissolved, bitter, exhilarating principle. Dr. DONOVAN recommends that the whole of the water to be used be divided into two parts, one half to be put on the fire with the coffee, and, as soon as the liquor boils, taken off, allowed to subside for a few seconds, and then poured off as clear as it will run. Immediately the remaining half of the water, at a boiling heat, is to be poured on the grounds; the coffee pot is to be placed on the fire and kept boiling three minutes, and after a few moments' settling, the clear part is to be poured off and mingled with the first. The mixture now contains a large share of the qualities of the coffee, both aromatic and bitter.

566. **Alkaline Water for Coffee-making.**—It is observed, that some natural waters give a stronger and better flavored coffee than others, and this has been traced as in Prague, to the presence of alkaline matter in those which give the most agreeable infusion. Hence, to obtain a more uniformly strong and well-flavored coffee, it is recommended to add a little soda to the water with which the infusion is made. About forty grains of dry, or twice as much of crystallized carbonate of soda, are sufficient for a pound of coffee.—(JOHNSTON.)

567. **Adulterations of Coffee.**—Ground coffee is very extensively adulterated. Various substances are employed for this purpose, as

roasted peas, beans, and corn, and dried and roasted roots, such as turnips, carrots, potatoes, &c. But the most common adulterant is *chiccory*, a plant of the dandelion tribe, which has a large, white parsnip-like root, abounding in a bitter juice. The root is mashed, sliced, dried, and roasted with about two per cent. of lard, until it is of a chocolate color. A little roasted chiccory gives as dark a color and as bitter a taste to water, as a great deal of coffee; and, costing only about one-third as much, the temptation is strong to crowd it into ground coffee. So common has the use of chiccory with coffee, become, that it has, in fact, created a taste for a solution of unmingled chiccory, as a beverage, although it is destitute of any thing corresponding to the cafein, or exhilarating principle of coffee. As an illustration of the extent of adulteration, and how one fraud opens the door to another, it is found that pure chiccory is almost as difficult to be met with in market as unadulterated coffee. Venetian red is employed to impart to it a true coffee color, while brick dust is used by the painter to cheapen and modify the shade of his Venetian red.

568. **How the Cheats in Coffee may be Detected.**—When cold water is poured upon coffee the liquid acquires color only very slowly, and it does not become very deep after prolonged soaking; even when boiling water is employed, the infusion, although somewhat deeper, still remains clear and transparent. When, however, cold water is poured upon roasted and ground chiccory root, it quickly becomes of a deep brown, and in a short time is quite opaque; with boiling water the result is still more prompt and marked. We may therefore detect chiccory in a suspected sample of coffee by placing a little in cold water. If it be pure the water will remain uncolored; if chiccory be present it will be strongly discolored. It may be remarked, however, that if the coffee should be adulterated with burnt sugar, it will produce a similar coloration of the water. It may be further noticed that particles of coffee float upon water, and, owing to their oiliness, are not melted, while chiccory absorbs water and sinks. The admixture of burnt and ground beans, peas, and grain, is not so readily shown. The most certain method of detecting these is by microscopic examination.

3. Cocoa and Chocolate.

569. **Source and Composition of Cacao Seeds.**—These beverages are prepared from the *cacao* beans, which are derived from a fruit resembling a short, thick cucumber, grown upon the small cacao tree of the West Indies, Mexico, and South America. The beans are enclosed in

rows, in a rose-colored, spongy substance, like that of the watermelon. When shelled out of this fleshy part, they are surrounded by a thin skin or husk, which forms about 11 per cent. of their weight. The cacao bean is brittle, of a dark brown color internally, cuts like a rich nut, and has a slightly astringent, but decidedly bitter taste. In preparing it for use, it is roasted, in the same way as coffee, until the aroma is fully developed. The bean is now more brittle, lighter brown in color, and less astringent and bitter than before. The following is its composition, according to LAMPADIUS:

Fatty matter,	53·16
Albuminous brown matter, containing the aroma of the bean,	16·70
Starch,	10·91
Gum,	7·75
Lignin,	·90
Red coloring matter,	2·01
Water,	5·20
Loss,	3·43

The largest constituent is a fatty substance, called *butter of cacao*, of the consistence of tallow, white, of a mild, agreeable taste, and not apt to turn rancid by keeping. Cacao beans have also been found to contain a substance, in minute proportion, not included in this analysis, called *theobromin*, a nitrogenous body, similar in nature and properties to thein, of tea, and cafeine of coffee.

570. **Forms of Preparation.**—It is prepared in three ways. *First.* The whole bean, after roasting, is beat into a paste in a hot mortar, or ground between hot rollers. This paste, mixed with starch, sugar, &c., forms common cocoa, sold under various names, as 'rich cocoa,' 'flake cocoa,' 'soluble cocoa,' &c. These are often greatly injured from the admixture of earthy and other matters, which adhere to the husk of the beans. *Second.* The bean is deprived of its husk, and then crushed into fragments. These form commercial *cocoa nibs*, the purest state in which cocoa can be obtained from the retail dealer. *Third.* The bean, when shelled, is ground at once into a paste by means of hot rollers, mixed with sugar, and seasoned with vanilla, and sometimes with cinnamon and cloves. This paste forms chocolate.—(JOHNSTON.)

571. **How these preparations are used.**—*First*, the chocolate is made up into sweet cakes, sugar confectionery, &c., and is eaten in the solid state as a nutritious article of diet, containing in a small compass much strength-sustaining capability. *Second*, the chocolate or cocoa is scraped into powder and mixed with boiling water, and boiling milk, when it makes a beverage somewhat thick, but agreeable to the pal-

ate, refreshing to the spirits, and highly nutritious. *Third*, the nibs are boiled in water, with which they form a dark brown decoction, which, like coffee, is poured off the insoluble part of the bean. With sugar and milk this forms an agreeable drink, better adapted for persons of weak digestion than the entire bean. The husk is usually ground up with the ordinary cocoas, but it is always separated in the manufacture of the purer chocolates.

572. **Adulteration of Chocolate.**—Pure or genuine chocolate should dissolve in the mouth without grittiness, and leave a peculiar sensation of freshness, and after boiling it with water, the emulsion should not form a jelly when cold; if it does, starch or flour is present. Many of the preparations of the cocoa-nut, sold under the name of chocolate powder, consist of a most disgusting mixture of bad or musty cocoa-nuts, with their shells, coarse sugar of the very lowest quality, ground with potato starch, old sea-biscuits, coarse branny flour, animal fats (generally tallow). I have known cocoa-powder made of potato starch moistened with a decoction of cocoa-nut shells and sweetened with molasses; chocolate, made of the same materials, with the addition of tallow and ochre, a coarse paint. I have also met with chocolate in which brick-dust, or red ochre, had been introduced to the extent of 12 per cent.—(NORMANDY.) The temptation to fraud in these preparations seems to be as irresistible as in the case of ground coffee. There is no easy means of detection short of refined microscopic and chemical examination, so that the only practicable means of self-defence for the purchaser, is to deal only with traders of unquestionable integrity, where such can be found.

V.—PRESERVATION OF ALIMENTARY SUBSTANCES.

1. CAUSES OF THEIR CHANGEABLENESS.

573. **Why is it Necessary that Foods should be Perishable?**—As in the plan of nature the production of force depends upon change of matter, and as the fundamental purpose of animal life is the evolution of power, it is apparent that matter which is to act as food, must be capable of ready and rapid transformation. This inherent facility of change, by which alimentary substances are conformed to the deep requirements of the animal economy, renders them extremely transient and perishable. If they are designed for change *within* the body, they must be subject to change *without*. In order that the gluten of flour, for example, may pass readily through the successive changes of the animal organism, being converted first into blood, then into muscular

fibre, and then decomposed for the development of contractile force, it is necessary that this substance should be so loosely built up, the attractions amongst its atoms should be so feeble, that slight causes become capable of breaking down its chemical structure.

574. **Change of Nutrient Matter within and without the Body.**—It was formerly taught that the living body is the domain of a peculiar vital power, which suspends the ordinary destructive play of chemical affinities and physical forces, but that at death the vital energy ceases, and those forces resume their natural activity, causing the speedy disorganization of the inanimate organism. But this is hardly correct. The vital force, or whatever we may name the presiding agency of the living system, does not suspend physical and chemical laws, but only regulates, and as it were *uses* them. We have already seen that strictly chemical changes go on constantly in the body, and shall shortly have occasion to notice their extent (624). They are of the same kind (*oxidations*), are carried on by the same agent (*atmospheric air*), and yield the same final products (carbonic acid, water and ammonia), in both conditions. In the living fabric the decompositions are measured; while in the lifeless body they are uncontrolled, and quickly spread through the entire organic mass.

575. **Conditions of the Perishableness of Foods.**—Alimentary substances are by no means alike changeable; some keep longer than others under the same circumstances. There are certain specific causes of organic decomposition, and accordingly as these act conjointly, or with variable intensity, is the rate of putrefactive change. In chemical composition, vegetable and animal substances are much more complicated than mineral compounds, and hence they are less permanent. Generally, mineral substances are combined in the simplest and most stable way, containing but few atoms, and consisting of pairs of elements, with nothing to disturb their direct attraction for each other. On the contrary, organized substances, in some cases, contain several hundred atoms, and consist of three, four or five different elements, joined by complex affinities into delicate and fragile combinations. We have seen, in speaking of fermentation, that albuminous substances are, from this cause, most changeable, and are universally present in substances designed for food. Water is a large constituent of all alimentary bodies, in their natural state, and is highly promotive of chemical changes; indeed, it is indispensable to them. Temperature exerts an all-controlling influence—warmth favoring, and cold retarding, or arresting, these transformations. The atmospheric medium, which is in contact with every thing, contains an element

which is the ever-active and eternal enemy of organization. The insatiable hunger of oxygen gas for the elements of organic substances, is a universal cause of decomposition—it is the omnipresent destroyer, consuming alike the living and the dead (662). Putrefactive decay may also be prevented by certain chemical substances which are used for the purpose. A knowledge of the laws and conditions of organic decomposition, has led to various practical methods of controlling it, which constitute the *art of preserving*.

2. Preservation by Exclusion of Air.

576. **Oxygen as an exciter of decay.**—Other conditions being favorable, that is, moisture being present and a proper temperature, access of air starts decomposition,—it is the prime mover of the destructive processes. We have already noticed its mode of action, in speaking of fermentation (488). In the case of vegetables, as potatoes and apples, for example, if the air is excluded from their interior, they remain for a considerable time sound. But if we cut them, the oxygen quickly attacks the exposed surface and turns it brown, indicating the incipient stage of decay. When the surface of fruits and vegetables is injured, so that their juices come in direct contact with the air, the effect is at once seen. If an apple is bruised, the injured spot immediately turns dark, and decomposition gradually spreads from that point, until the whole apple becomes rotten. The juice of the ripe grape, while protected from air by an unbroken skin, remains sweet and scarcely changes; it may be dried and converted into a raisin, its sweetness remaining. If it be crushed under mercury, and the juice be collected in a glass completely filled with mercury, so as to prevent all contact of air, it will remain unchanged for several days. But if air be once admitted, as by perforating the grape-skin with a needle's point, fermentation commences almost instantaneously, and the juice is soon entirely changed. The same is true of all animal fluids. Milk, while in the udder of the healthy cow undergoes no change, but in contact with air, its properties are soon totally altered—it is soured and coagulated (547). When life has been destroyed by bodily wounds, decomposition spreads from them; or if the animal have not died by violence, the changes may begin internally in those parts, such as the lungs, which are in contact with the air.

577. **Changes begun by Oxygen may proceed without it.**—It is by no means necessary, in all cases, that air should be in *constant* contact with the changing substance; the decomposition once commenced,

may continue, though the oxygen be entirely excluded. Milk, if once exposed to the air, coagulates and sours, though sealed up in air-tight vessels. Grapè juice, though oxygen be completely cut off, ferments, generates gases, and often explodes the bottles in which it is confined. The impulse of disorganization being given, decomposition goes on without further external aid. To explain this, we must suppose that the atoms of the changing substance were at first in a kind of rest or equilibrium, without mutual activity, and that by the invasion of oxygen, this equilibrium has been disturbed, so that the elements of the substance begin to act and re-act upon each other, giving rise to new products. In this way, a state of change commenced by merely jostling a few surface atoms through contact of oxygen, is propagated by intestinal action throughout the entire mass.

578. **How changes begun by Oxygen may be stopped.**—"The property of organic substances to pass into a state of fermentation and decay in contact with atmospheric air, and in consequence to transmit these states of change to other organized substances, *is annihilated in all cases without exception, by heating to the boiling point.*"—Liebig. The substance most prone to be affected by air-contact, is liquid albumen; and this by boiling is solidified, and so altered in properties, as to lose its peculiar susceptibility of transmutation. The boiling certainly obliterates the effect that oxygen has produced, and as the atoms of matter have no inherent power to put themselves in motion, and cannot change place unless influenced by some external cause, it is obvious that the nutritive substance will remain unaltered *if the air is kept excluded.* These facts indicate the most certain, manageable, and perfect method of preserving alimentary substances. By simply heating to the boiling point, which produces no other change than that of partial cooking, and afterward protecting from the air, alimentary substances, both animal and vegetable, may be preserved in their natural condition entirely unchanged in both flavor and properties, for an indefinite period. This plan was first brought into general notice by M. Appert of France, in 1809. He preserved all kinds of fruits, vegetables, meats, soups, &c., in glass bottles. His practical methods, however, were crude and unsatisfactory, and have been superseded by others. Captain Ross presented the society of arts with a box from the house of Gamble and Darkin (London), which contained cooked provisions sixteen years old, and that were in a state of perfect preservation. The details of the preparation on a large scale, as practised chiefly for marine consumption, we have no space here to describe. The vegetables, meats, poultry, &c., are cooked precisely

in the same manner as for immediate consumption, and then sealed up in boxes and canisters which do not contain a particle of air.

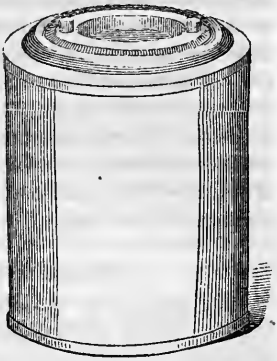
579. **Domestic preservation in air-tight vessels.**—The preservation of delicate fruit and vegetables in air-tight cans, has now become quite generally a household operation, and there can be no doubt that as people acquire experience in the process, they will employ it much more extensively. Of this process Prof. LIEBIG remarks, "The prepared aliments are enclosed in canisters of tinned iron plate (609), the covers are soldered air-tight, and the canisters exposed to the temperature of boiling water. When this degree of heat has penetrated to the centre of the contents, which it requires about three or four hours to acomplish, the aliments have acquired a stability which one may almost say is eternal. When the canister is opened, after the lapse of several years, the contents appear just as if they were only recently enclosed. The color, taste, and smell of the meat, are completely unaltered. This valuable method of preparing food, has been adopted by many persons in my neighborhood, and has enabled our housewives to adorn their tables with green vegetables in the midst of winter, and with dishes at all times which otherwise could be obtained only at particular seasons."

580. **Canisters closed by soldering.**—Perfectly tight tin canisters of almost any convenient shape are provided, and the article to be preserved, sometimes raw, but generally cooked, is placed within it, and the lid soldered down. The lid, is however, perforated with a small aperture or pin-hole. The canister is then placed in boiling water, and the moisture within is converted into steam which drives out the air. The boiling is continued as long as may be required totally or partially to cook the contents of the can, which is then withdrawn, and the pin-hole closed with solder. This is an operation of considerable nicety. The heat drives out not only air contained in the canister, but also a jet of steam. The solderer, therefore, lets fall a few drops of cold water on the tin around the aperture, producing a momentary condensation of the steam, during which the pin-hole is dexterously closed. The delicacy and success of the operation, consists in carrying the condensation only so far as just to arrest the jet of steam, and in closing the opening at the instant. After the canister is closed, it is again exposed with its contents for a short period to a boiling heat.

581. **Spratt's self-sealing Cans.**—In many cases a tinsmith may not be near, and the soldering operation for closing the canisters will be quite certain to fail in the hands of the inexperienced. To obviate

this difficulty, other arrangements have been contrived. SPRATT'S cans* are oblong tin cylinders (Fig. 106), holding from a quart to a gallon, which are closed with a screw acting upon a ring or 'compress' of india-rubber, and then hermetically sealed with beeswax. The closure is simple and effectual, and can be managed with a little care by any body. The articles being introduced into the can, the cap is screwed down tightly *with the fingers*, and the can submerged in a boiler of cold water, which is then raised to boiling. After boiling a sufficient time they are withdrawn, the caps unscrewed, and the cans left open for one minute. If the previous boiling has been thorough, steam will escape freely. If it does not so escape, the boiling must be repeated. The cap is then screwed down, this time very tightly, *with a wrench provided*, and the can introduced into the water and boiled a second time. On withdrawing it again melted beeswax is poured into a little channel or groove, which makes the sealing perfect, if the cap fits and is tightly screwed down. In all cases there are at least two boilings. The second might be thought unnecessary, but it is not. The vessel must be opened, that the steam may drive out the air, and there is always the possibility that a trace may be left. If so, during the second boiling the oxygen will be entirely converted into carbonic acid, which is innoxious. As the results of large experience the times required for the boiling are as follows:

FIG. 106.



Spratt's Self-sealing Can.

	First boiling.	Second boiling.
Berries of all kinds	15 minutes.	5 minutes.
Cherries or currants	15 "	5 "
Rhubarb	15 "	5 "
Peaches	20 "	5 "
Plums	20 "	10 "
Quinces, pears or apples	45 "	15 "
Tomatoes	30 "	15 "
Asparagus	60 "	30 "
Green peas, corn or beans	3 hours.	3 hours.

582. **Suggestions concerning the use of the Cans.**—None but perfectly fresh sound fruit should be put up in the above manner. It is recom-

* Manufactured by WELLS & PROVOST, New York.

mended that peaches, quinces, pears and apples be peeled, and the seeds removed before preserving, as seeds and peel embitter and otherwise injure the flavor. Peach stones contain traces of Prussic acid, a powerful poison, which, if the fruit be preserved whole, is liable to be diffused through it. Fruits are preserved either with or without sugar; if without, a quarter of a pint of water should be poured over every quart of fruit while in the can. If the fruit is to be sweetened, make a sirup, and pour on it in the can, until it is nearly full. A sirup for summer fruits is made by adding a pound of crushed sugar to a pint of water, and boiling two minutes. Very acid fruits, such as quinces and plums, require a stronger sirup, say $1\frac{1}{2}$ lb. sugar to a pint of water. If the cans are not perfectly tight when the steam condenses within, forming a vacuum, the external pressure of the air may drive the soft beeswax in through the crevice. Aliments well put up will keep in a room at any temperature; if the cans bulge, it is a sign of development of gas by internal decomposition, and their contents will not keep.

3. Preservation at low Temperatures.

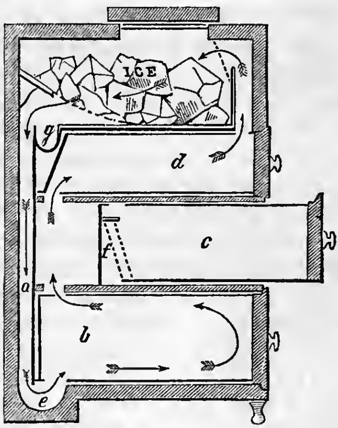
583. **Influence of Temperature.**—Degrees of temperature exert an absolute control over the duration of alimentary compounds. At 32° their juices are congealed, and they remain totally unchanged. At a few degrees above the freezing point changes are very slow. As we ascend the scale, the conditions of mutation become more favorable, except in the case of albumen, which is rendered more enduring by the heat of coagulation. In all other cases decomposition proceeds more rapidly as warmth increases, until the point of quick disorganization, charring, and active combustion is reached.

584. **Freezing as a means of Preserving.**—Congelation, therefore, may be resorted to as a means of preservation, chemical action being impossible where the substance is reduced to a solid state. Remarkable cases are on record in which the bodies of animals have been disentombed from masses of ice, in such a state of preservation that the flesh was fit to support nutrition, although they had been wrapped in ice for such a vast period that the race to which they belonged had become extinct. It is customary in many regions to preserve fresh meat by freezing it, and packing in snow. Some object that the flavor of meat is injured by freezing; but the Russians, on the contrary, insist that it is improved. Great care is necessary in thawing all frozen aliments, whether meat, fish, or vegetables. It should be done slowly, and the best way is by immersion in very cold water.

A shell of ice will be formed around them, as we have often seen in 'taking the frost out of apples;'—the water in contact with the surface being frozen into a scale, by parting with its heat to thaw the frozen apple within. If thawed too rapidly, as by placing them in a warm room or in hot water, the taste is impaired, and the composition of the substance so affected that putrefaction is rapidly brought on. One of the effects of freezing and thawing potatoes and some fruits, is to increase the amount of sugar, as shown by their sweeter taste.

585. **Low Temperatures above Freezing—Refrigerators.**—We command low temperatures by cellars, and the use of ice. Excavations made below the surface of the ground have a temperature common to the surrounding strata of earth, which is cooler the deeper we go for nearly a hundred feet. The temperature is also very constant, the extremes of winter and summer being both excluded. The temperature of good cellars (40° to 60°), is below the range most favorable to putrefaction (60° to 100°). By the use of ice in the ice-house or refrigerator, the temperature may be kept down to within 5° or 10° of freezing. At these points changes proceed slowly, so that meat admits of being kept at this degree of coolness for a considerable time. It is said that meat should never be suffered to *touch* ice, as it is toughened and otherwise injured. The refrigerator is commonly a rude, shelved box. If opening at top, it is troublesome of access and difficult to make its space available. If it have doors at the sides, the cold air flows out every time it is opened; and if the ice is placed at the bottom, there is no circulation of air or means of cooling the upper space. A. S. Lyman, of N. Y., has obviated these defects by a newly devised arrangement (Fig. 107). The ice is placed in an upper chamber over a grate opening to the flue *a*, through which, ice-cold air constantly falls. The body of the refrigerator is occupied by three drawers, *b c d*, *c* being represented as partially withdrawn. The cold air fills these drawers, and as it becomes slightly warmer is pressed

Fig. 107.



Lyman's Bureau Refrigerator.

upward in the direction of the arrows, and re-cooled by contact with the ice. It descends again through the flue, the temperature of the whole refrigerator being thus kept down nearly to freezing. The waste water is caught at *g*. The arrangement of drawers makes the whole space available, and is as convenient as a common bureau. When one is partially withdrawn, as at *e*, the air in, it being heavier than that of the room, does not escape, while the circulation of air continues within. There is also a twofold means of purifying the air. At *f* there is a filter consisting of a wire-gauze box, through which the air passes and is disinfected. When it comes in contact with the ice, it is condensed and its moisture deposited, so that it has a real drying effect upon the articles to be preserved. The water constantly forming by the melting ice is highly absorbent of the gases set free by decomposing food, so that these impurities are constantly washed out of the air in its progress. The charcoal filter, in effect, divides the space into two refrigerators; thus preventing articles in one from smelling or tasting of those in the other. Cars are constructed upon this principle, in which meat is transported from the Western States to New York in summer.

586. **Keeping Fruits at low Temperatures.**—The most important fact relating to the composition of fruits is the large proportion of water they all contain, and which constitutes the bulk of their peculiar juices. From three-fourths to nine-tenths of them being liquid, we are to regard them as consisting of a small amount of solid matter diffused through from four to ten times their bulk of water. This condition is eminently favorable to the action of fruits upon the organs of taste in their natural or uncooked state; being in a kind of pulpy, half-dissolved condition, they are ready to take prompt effect upon the pappilæ of the mouth. But the same property of fruits which adapts them so perfectly to our gustatory enjoyment, shortens the time when they can be so employed. Their abounding moisture favors decomposition, and they are hence perishable and short-lived. Yet by proper management fruits may be long preserved in a fresh and perfect state. Vegetables and juicy fruits, as apples and pears, can be preserved for months in cellars where the necessary warmth for inducing decay is not attained. Sometimes fruit, as many varieties of apples, are not really ripened at the time of gathering, but undergo a slow change during the winter months, their acid principle being converted into sugar. To be best preserved fruit should be picked when perfectly dry, at a time when the stalk separates easily from the spur. Apples and pears should have their stalks or "stems" separated from

the *tree*, and not from themselves. The utmost care should be observed to prevent bruises or contusions; some have implements for collecting the most valuable kinds of fruit, so as not to touch it with the hand. The most delicate kinds do not bear handling or wiping, as this rubs off the bloom which, when allowed to dry on some fruits, constitutes a natural varnish, closing up the pores and preventing the evaporation of the juices. Apples have been preserved a year in a fine fresh condition, by keeping them in an atmosphere within ten degrees of the freezing point. Constancy of temperature is important, as alternations of heat and cold, by contracting and expanding the juices, seem to favor chemical changes. Grapes, cherries, currants, gooseberries, and other soft fruits have been preserved for use in winter by gathering them when not too ripe, and when very dry putting them unbruised into dry bottles, which are afterwards well corked, and then buried in the earth. The efficiency of this method of preserving is increased by immersing the bottles containing the fruit for a few minutes previously to corking, in hot water, which coagulates the vegetable albumen. The preservation is here due to the joint influence of exclusion of air, and a low and uniform temperature. A *preservatory* for fruit, or kind of refrigerator on a large scale, has been devised by Mr. PARKER. The fruit, picked carefully and unbruised, is conveyed at once to the preservatory, where the temperature is down nearly to freezing. The plan requires that ice be supplied the previous winter.

4. PRESERVATION BY DRYING.

587. **Retention of Water in Fruits and Vegetables.**—As nature places water in large quantities in organic bodies, in many cases she takes due precautions to keep it there. Unripe potatoes and unripe apples removed from the parent stock shrivel, shrink, and perish. These effects result from the porous condition of the immature skin, which permits the water within to escape by evaporation. "But when ripe this porous covering has become chemically changed into a thin impervious coating of *cork*, through which water can scarcely pass, and by which, therefore, it is confined within for months together. It is this cork layer which enables the potato to keep the winter through, and the winter pear and winter apple to be brought to table in spring of their full dimensions."—(JOHNSTON).

588. **Loss of Water as a means of Preservation.**—Yet as organic substances may be kept by *solidifying* the water, that is, freezing them, they may also be preserved by *withdrawing* it. Both vegetable and animal substances are extensively preserved in this way. Drying is a

kind of disorganization of the alimentary body, its largest constituent being removed; yet, in this case, the lost ingredient may be added again, and the substance brought into a condition more or less resembling the natural state. Drying is effected either by simple exposure to the sun and air, or by artificial heat of a higher intensity, applied in various ways. Both methods are quite practicable, but have their disadvantages. Drying in the air is necessarily a slow process, so that there is danger of moulding and fermentation; the substances require to be made small or thin, and as the air itself is moist, the drying can never be complete, but only reaches a certain point, and then fluctuates with the varying atmospheric dampness. On the other hand, when artificial heat is employed, as in kiln-drying in close apartments, it is obvious that the foods are liable to be much altered in their nature. The starch may be dissolved, or altered to gum; the sugar browned and changed to caramel, acquiring a bitter, disagreeable taste, if the heat of the drying chamber be too high; while if the temperature be not higher than 140°, the albumen may be *dried* so as to dissolve again in water; if higher, it is *coagulated*, and remains insoluble.

589. **Preserving Succulent Vegetables.**—These, if exposed to the air, evaporate their moisture, wilt, and lose their crispness and freshness. A damp cool place is best to prevent these changes for a time. Many are kept soundly during winter by burying in the earth. M. MASSON, head gardener to the Horticultural Society of Paris, has described a mode of preserving succulent vegetables by drying and compression. He prepares cabbage, cauliflower, potatoes, spinach, endive, celery, parsley, &c., in such a manner that they keep for any length of time, and when soaked in water resume much of their original freshness and taste. They are chiefly prepared for marine consumption. The packages of dried vegetables are covered with tinfoil. Dr. HASSALL speaks of a specimen of dried cabbage as follows: "On opening the package the contents, which formed a solid cake, were seen to consist of fragments of leaves of a yellowish color, interspersed here and there with some that were green. In this state it was difficult to determine what the nature of the vegetable was. Soaked in hot water for about half an hour, it gradually underwent a great expansion, so that it acquired several times its former bulk. When examined, it was evident at a moment's glance that the vegetable consisted of the sliced leaves of the white-hearted garden cabbage, presenting the appearance and color, and possessing the taste and smell, to a remarkable extent, of the vegetable in its recent state."

5. Preservation by Antiseptics.

590. **Remarkable properties of common Salt.**—*Antiseptics* are opposers of putrefaction. Certain bodies when added to organized substances, possess the power of resisting or preventing their putrefactive decomposition; they are numerous, and act in various ways. Those used for preserving aliments are salt-petre, sugar, alcohol, creosote, vinegar, oil, and common salt. However 'common' this last substance may be, we shall nevertheless be interested in giving it a moment's attention. Though mild and pleasant to the taste, it is composed of two elements, one a yellowish green, suffocating, poisonous gas, *chlorine*, and the other a bright silvery-looking metal, *sodium* (hence the chemical name of the substance *chloride* of *sodium*). When these two elements are brought together, they unite spontaneously; and yet so prodigous is the force with which they combine, so enormous the condensation of matter, that although the sodium unites with more than five hundred times its bulk of the heavy gas, yet the compound formed occupies less space than the solid sodium *alone* did before the union. No known mechanical force could have accomplished this, yet it results from the agency of chemical affinity (Farraday). If a lump of common salt, (it occurs in large masses in the shape of *rock salt*,) be cut into the form of a thin plate, and held before a fire, it does not stop the heat-rays, but has the singular property of permitting them to dart through it, as light does through glass—*it is the glass of heat.* A hundred lbs. of water, hot or cold, dissolve 37 of salt, forming a *saturated solution* or the strongest brine. When the briny solution evaporates, the salt reappears in the solid form, or crystallizes. Its crystals are cube shaped; if the evaporation takes place slowly they are large, but if it be rapid, they are small, and formed in a curious manner. Resulting from evaporation, they are naturally formed at the surface of the liquid, and present the appearance of little floating cubes, as shown in (Fig. 108), where the solid crystal is upborne or floats in a little depression of the fluid surface. New crystals

Fig. 108.

Fig. 109.

Fig. 110.

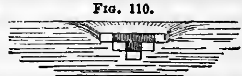


Fig. 111.

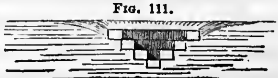
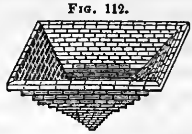


Fig. 112.



How crystals of common salt are formed.

soon form, which are joined to the first at its four upper edges, constituting a frame above the first little cube (Fig. 109). As the whole descends into the fluid, new crystals are grouped around the first frame constituting a second (Fig. 110). Another set added in the same way gives the appearance shown in Fig 111. The consequence of this arrangement is that the crystals are grouped into hollow, four-sided pyramids, the walls of which have the appearance of steps, because the rows of small crystals retreat from each other. This mode of grouping is called *hopper-shaped* (Fig. 112).

591. **Sources and Purification of Salt.**—Salt is obtained from three sources; *first*, it is dug from the earth in mines, in large masses, like transparent stones (*rock salt*); *second*, it is procured by evaporating sea-water (*bay salt*); and, *third*, by boiling down the liquid of brine springs. It differs very much, in purity, from different sources, being in many cases contaminated by salts of calcium and magnesium, which render it bitter. Pure salt, in damp weather, attracts water from the atmosphere, and becomes moist, but parts with it again when the weather becomes dry. But the chlorides of calcium and magnesium are much more absorbent of water, and hence, if the salt is damp and moist when the air is dry, we may infer that a large proportion of these substances is present in it. Salt, for certain culinary purposes, as for salting butter, should be perfectly pure. Its bitter ingredients are more readily soluble in water than is the salt itself; hence, by pouring two or three quarts of boiling water upon ten or twenty lbs. of salt, stirring the whole well now and then for a couple of hours, and afterwards straining it through a clean cloth, the obnoxious substances may be carried away in solution. Among the purest, is that called Liverpool salt, which is an English rock-salt dug from the mines; dissolved, recrystallized and ground.

592. **How salt preserves meat.**—Salt is more widely used than any other agent in conserving provisions, especially meats. It is well known that when fresh meat is sprinkled with dry salt, it is found after a few days swimming in brine, although not a drop of water has been added. If meat be placed in brine it grows lighter, while the quantity of liquid is increased. The explanation of this is, that water has a stronger attraction for salt than it has for flesh. Fresh meat contains three-fourths of its weight of water, which is held in it as it is in a sponge. Dry salt will extract a large part of this water, dissolving in it and forming a saline liquid or brine. In this case, the water of the meat is divided into two parts; one is taken up by the salt to form brine, while the other is kept back by the

meat. The salt robs the meat of one-third or one-half the water of its juice. Salting is therefore only an indirect mode of drying; the chief cause, perhaps, of the preservation of the meat, being, that there is not sufficient water left in it to allow putrefaction. The surrounding brine does not answer this purpose, as it does not act upon the meat; its relation to flesh being totally different to that of fresh water. If fresh water be applied to a piece of dry meat, it is seen to have a strong attraction for it, but if we use even a weak solution of salt, it flows over it wetting it but very imperfectly.

593. **How meat is injured by salting.**—The separation of water from the fibre of meat shrinks, hardens, and consequently renders it less digestible. It is quite probable, also, that the salt, in some way not yet understood, combines with the fibre itself, thus altering injuriously its nutritive properties. PEREIRA thinks that the separation of water is not sufficient alone to account for its preservative action, but that it must produce some further unexplained effect upon the muscular tissue. The main and well-established injury of salting, however, is caused by the loss from the meat of valuable constituents, which escape along with the water which the salt withdraws. It has been shown that the most influential constituents of meat are dissolved in its juice (471). The salt, therefore, really abstracts the *juice of flesh* with its albumen, kreatine, and valuable salts; in fact, the brine is found to contain the chief soup-forming elements of meat. Salting, therefore, exhausts meat far more than simple boiling, and as the brine is not consumed, but thrown away, the loss is still greater In salting meat, however, there happens to be a slight advantage resulting from its impurities, lime and magnesia. These are decomposed by the phosphoric acid of the juice of flesh, and precipitated upon the surface, forming a white crust, which may often be observed upon salt meat; this constituent, therefore, is not separated in the brine. Saltpetre has a preservative effect, probably in the same way as common salt, but it is not so powerful, and unlike salt produces a reddening of the animal fibres. A little of it is often used along with salt for this purpose.

594. **Salting Vegetables.**—These may be preserved by salt, as well as flesh, but it is not so commonly done. In salting vegetables, however, a fermentation ensues, which gives rise to *lactic acid.* This is the case in the preparation of *sauerkraut* from cabbages, and in salting cucumbers. The brine with which both vegetables are surrounded is found strongly impregnated with both lactic and butyric acids.

595. **Preservation by Sugar.**—This is chiefly employed to preserve

fruits. Many employ both sugar and molasses for the preservation of meat; sometimes alone, but more commonly united with salt. The principle of preserving by means of sugar is probably similar to that of salting. In the case of fruits, the sugar penetrates within, changing the juices to a sirup, and diminishing their tendency to fermentation or decomposition. Weak or dilute solutions of sugar are, however, very prone to change; they require to be of a thick or sirupy consistence. KNAPP states that the drops of water which condense from the state of vapor on the sides of the vessels in which the preserves are placed, are often sufficient to induce incipient decomposition, by diluting the upper layers of sugar. The effect of the acids of fruits is gradually to convert the cane sugar into uncrystallizable and more fermentable grape sugar.

596. **Preserving by Alcohol and other substances.**—Strong alcoholic liquors are used to prevent decomposition in both vegetable and animal bodies. They penetrate the substance, combine with its juices, and as the organic tissues have less attraction for the spirituous mixture, it escapes; and the tissues themselves shrink and harden in the same way as when salted. Alcohol also obstructs change by seizing upon atmospheric oxygen, in virtue of its superior attraction for that gas, and thus preventing it from acting upon the substance to be preserved. *Vinegar* is much used for preserving, but how it acts has not been explained. *Spices* exert the same influence. *Creosote*, a pungent compound existing in common smoke, and which starts the tears when the smoke enters the eyes, is a powerful antiseptic, or preventor of putrefaction. Meat dipped for a short time in a solution of it will not putrefy, even in the heat of summer. Or if exposed in a close box to the vapor of creosote, the effect is the same, though in both cases the amount producing the result is extremely small. The preservative effect of smoke-drying is partly due to creosote, which gives to the meat its peculiar smoky taste, and partly to desiccation. *Oil* is but little employed in saving alimentary substances—two kinds of fish, *anchovies* and *sardines*, are preserved in it. *Charcoal* has always been ranked as an antiseptic or arrester of putrefaction; but it has been lately shown that it is rather *promotive* of decomposition. How this is, will be explained in another place (811).

6. PRESERVATION OF MILK, BUTTER, AND CHEESE.

597. **Modes of preserving Milk.**—The cause of the souring of milk we have seen to be the action of oxygen upon its casein, which alters the sugar to acid (547). If, therefore, the milk be tightly bottled, and

then boiled, the fermentative power of the curdy matter is destroyed, and it may be kept sweet for several months. When, however, the milk is again exposed to the air, the curd resumes its power of acting upon sugar, and acid is again formed. When milk is kept at a low temperature, the cold retards its changes. If the vessels containing it are placed in a running stream of cool water, or in a place cooled by ice, it will remain cool for several days. Milk may also be prevented from souring, even in warm weather, by adding to it a little soda or magnesia. The alkali destroyes the acid as fast as it is produced, and the liquid remains sweet. The small quantity of lactate of soda or magnesia which is formed, is but slightly objectionable. If milk be evaporated to dryness, at a gentle heat, with constant stirring, it forms a pasty mass, which may be long kept, and which reproduces milk when again dissolved in water. *Alden's concentrated milk* is a solidified pasty preparation, made by evaporating milk, with sugar, and affords an excellent substitute for fresh milk, in many cases, when dissolved in water.

598. **Unpurified Butter quickly spoils.**—Butter when taken from the churn contains more or less of all the ingredients of milk, water, casein, sugar, lactic acid, which exist in the form of buttermilk, diffused through the oily mass. CHEVREUL states that fresh butter yields 16 per cent. of these ingredients, chiefly water, and 74 of pure fat. In this state butter cannot be kept at all. Active decomposition takes place almost at once, the butter acquires a bad odor, and a strong disagreeable taste. The casein passes into incipent putrescence, generating offensive compounds, from both the sugar and oily matter.

599. **Butter Purified by Mechanical Working.**—It is obvious, therefore, that in order to preserve butter, it must first be freed from its buttermilk, which is done by working it, over and over, and pressing or squeezing it, which causes the liquid slowly to ooze out and flow away. The working or kneading is done with a wooden ladle, or a simple machine adapted to the purpose, or else by the naked hand. It is objected that the employment of the hand is apt to taint the butter by its perspiration; but while it is admitted that *moist* hands should never do the work, many urge that those which are naturally cool and dry, and made clean by washing in warm water and oatmeal (*not soap*), and then rinsed in cold water, will remove the sour milk from the butter more effectually than any instrument whatever, without in the least degree injuring it. Overworking softens butter, renders it oily, and obliterates the grain.

600. **Preparation of Butter by Washing.**—Some join washing with

mechanical working, to separate the buttermilk. It is objected to this, first, that water removes or impairs the fine aroma of the butter, and, *second*, that it exposes the particles of butter to the injurious action of air much more than mechanical working. On the other hand, it is alleged that without water we cannot completely remove the fermenting matter, the smallest portion of which, if left in the butter, ultimately injures it. If water be used, it is of the utmost consequence to guard against its impurities. It is liable to contain organic substances, vegetable or animal matter, in solution, invisible, yet commonly present, even in spring water. These the butter is sure to extract, and their only effect can be to injure it. The calcareous waters of limestone districts are declared to be unfit for washing butter. SPRENGEL states that the butter absorbs the lime, and is unpleasantly affected by it. A. B. DICKINSON is of opinion that the best butter cannot be made where hard water is used to wash it; he employs only the softest and purest for this purpose.

601. **Cause of Rancidity in Butter.**—Pure oil has little spontaneous tendency to change. If lard, for example, be obtained in a condition of purity, it may be kept sweet for a long time without salt, when protected from the air. That it *does* alter and spoil in many cases, is owing to traces of nitrogenous matter, animal membranes, fibres, &c., which have not been entirely separated from it. These pass into decomposition, and carry along the surrounding oily substance. So with butter; when pure, and cut off from the air, it may be long kept without adding any preservative substance. But a trifling amount of curd left in it is sufficient to infect the whole mass. It is decomposed, and acting in the way of ferment upon the sugar and oily substance itself, develops a series of acids, the *butyric*, which is highly disagreeable and offensive, and the capric and caproic acids, which have a strong sour odor of perspiration. The butter is then said to be *rancid.* In general, the more casein is left in butter, the greater is its tendency to rancidity.

602. **Action of Air upon Butter.**—The fat of butter is chiefly composed of *margarin*, which is its main solidifying constituent, and abounds also in human fat. It is associated with a more oily part, *olein.* Now, air acts not only upon the curdy principle, causing its putrescence; but its oxygen is also rapidly absorbed by the oleic acid. One of the effects of this absorption may be to harden it, or convert it into margaric acid. This is, however, a first step of decomposition, which, when once begun, may rapidly extend to the production of various offensive substances. When, therefore, butter is much exposed to the

air it is certain to acquire a surface rancidity, which, without penetrating into the interior, is yet sufficient to injure its flavor. It is indispensable to its effectual preservation that the air be entirely excluded from it. Hence, in packing butter, the cask or firkin should be perfectly air tight. Care should be taken that no cavities or spaces are left. If portions of butter are successively added, the surface should be either removed or raised up in furrows, that the new portion may be thoroughly mixed with it, or it should be kept covered with brine, and the vessel ought not to be finally closed until the butter has ceased shrinking, and the vacancies that have arisen between the butter and vessel's sides are carefully closed.

603. **Substances used to preserve Butter.**—Salt, added to butter, performs the twofold office of flavoring and preserving it. The salt becomes dissolved in the water contained in it, and forms a brine, a portion of which flows away, while the butter shrinks and becomes more solid. Salt preserves butter by preventing its casein from changing; hence the more of this substance is left in it the more need of salt. The quantity used is variable, from one to six drachms to the pound of butter. It is objected to salt that it masks the true flavor of butter, especially if it be not of the purest quality (591). Saltpetre will preserve butter; but it is less active than common salt, and some think its flavor agreeable. Sugar is sometimes added to aid in preservation, and to compensate for the loss of the sugar of milk. Honey has been also used for the same purpose, at the rate of an ounce to the pound of butter. Some employ salt, saltpetre, and sugar all together. From an examination of upwards of forty samples of English butter, Hassall found the proportion of water in them to vary from 10 to 20, and even 30 per cent., and the proportion of salt from one to six or seven per cent. A simple method of ascertaining the quantity of water in butter is, to melt it and put it in a small bottle near the fire for an hour. The water and salt will separate and sink to the bottom.

604. **Changes of Cheese by Time.**—Cheese requires time to develop its peculiar flavor, or ripen. A slow fermentation takes place within, which differs much according to the variety of circumstances connected with its preparation, and the degree and steadiness of the temperature at which it is kept. The fermentation, which is gentle and prolonged at a low temperature, becomes too rapid in a warm, moist place. The influence of temperature is shown by the fact that in certain localities of France, especially at Roquefort, there are subterranean caverns which rent and are sold at enormous sums for the purpose of keeping

and maturing cheese. These natural rock-cellars are maintained, by gentle circulation of air, at 41° to 42°. The nature of the changes that cheese undergoes has not been clearly traced. It is known that the casein becomes so altered as to dissolve in water. The salt introduced to preserve it is said to be decomposed; the oily matter gets rancid, as may be shown by extracting it with ether; and peculiar volatile acids and aromatic compounds are produced. Cheese of poor or inferior flavor, it is said, may be inoculated with the peculiar fermentation of a better cheese, by inserting a plug or cylinder of the latter into a hole made to the heart of the former. To prevent the attacks of insects the cheese should be brushed, rubbed with brine or salt, and smeared over with sweet oil, the shelves on which they rest being often washed with boiling water.

605. **Preservation of Eggs.**—When newly laid, eggs are almost perfectly full. But the shell is porous, and the watery portion of its contents begins to evaporate through its pores the moment it is exposed to the air, so that the eggs become lighter every day. As the water escapes outward through the pores of the shell air passes inward and takes its place, and the amount of air that accumulates within depends, of course, upon the extent of the loss by perspiration. Eggs which we have preserved for upward of a year, packed in salt, small ends downwards, lost from 25 to 50 per cent. of their weight, and did not putrefy. As the moisture evaporated the white became thick and adhesive, and the upper part was filled with air. To preserve the interior of the egg in its natural state, it is necessary to seal up the pores of the shell air-tight. This may be done by dipping them in melted suet, olive oil, milk of lime, solution of gum arabic, or covering them with any air-proof varnish. They are then packed in bran, meal, salt, ashes, or charcoal powder. Reaumur is said to have coated eggs with spirit varnish, and produced chickens from them after two years, when the varnish was carefully removed.

VI.—MATERIALS OF CULINARY AND TABLE UTENSILS.

606. It seems important in this place to offer some observations pertaining to our ordinary kitchen and table utensils. We speak of the chemical properties of their materials rather than of their mechanical structure.

607. **Utensils of Iron.**—Iron is much employed for vessels in kitchen operations. The chief objection to it springs from its powerful attraction for oxygen, which it obtains from the atmosphere. It will even

decompose water to get it. In consequence of this strong tendency to oxidation, its surface becomes corroded and roughened by a coating of rust, which is simply *oxide of iron.* The rust combines with various substances contained in food, and forms compounds which discolor the articles cooked in iron vessels, and often impart an irony or styptic taste. Fortunately, however, most of these compounds, although objectionable, are not actively poisonous; yet, sulphate of iron (copperas) and some other mineral salts of iron, are so. Cast iron is much less liable to rust than malleable, or wrought iron. There is one mode of managing cast iron vessels, by which the disagreeable effects of rust may be much diminished, if not quite prevented. If the inside of stew-pans, boilers, and kettles be simply washed and rinsed out with warm water, and wiped with a soft cloth instead of being scoured with sand or polishing materials, the vessel will not expose a clean metallic surface, but become evenly coated with a hard, thin crust of a dark brown color, forming a sort of *enamel.* If this coating be allowed to remain, it will gradually consolidate and at last become so hard as to take a tolerable polish. The thin film of rust thus prevents deeper rusting and at the same time remains undissolved by culinary liquids.

609. **Protection of Iron by Tin.**—As such protection, however, involves care and consideration, it is uncertain and unsatisfactory, and besides it is inapplicable to vessels of thin or sheet iron. A better method is that of coating over the iron with *metallic tin*, which has come into universal use in the form of *tin-ware.* The sheet tin which is so widely employed for household utensils is made by dipping polished sheet iron in vats of melted tin. Tin itself is a metal somewhat harder than lead, but is never used for culinary vessels. What is called *block tin* is generally supposed to consist of the pure metal. This is an error. It is only tinned iron plate, better planished, stouter, and heavier than ordinary. All tin ware, therefore, is only iron plate coated or protected by tin: yet, practically, it is the metallic tin only that we are concerned with, as that alone comes in contact with our food.

610. **Adaptation of Tin to Culinary Purposes.**—Tin, in its metallic state, seems to have no injurious effect upon the animal system, for it is often given medicinally in considerable doses, in the form of powder and filings. It is frequently melted off from the sides of sauce-pans or other vessels in globules, and is thus liable to be swallowed, a circumstance which need occasion no alarm. The attraction of tin for oxygen is feeble, and it therefore oxidizes or rusts very slowly. Strong acids, as vinegar or lemon juice, boiled in tin-coated vessels, may dis-

solve a minute portion of the metal, forming salts of oxide of tin, but the quantity will be so extremely small that it need excite little apprehension. It is a question among toxicologists whether its oxide be poisonous. PROUST showed that a tin platter, which had been in use two years, lost only four grains of its original weight, and probably the greater part of this loss was caused by abrasion with whiting, sand, or other sharp substances during cleansing. If half of it had been taken into the system dissolved, it would have amounted only to $\frac{1}{365}$ of a grain per day, a quantity too trifling to do much harm, even if it were a strong poison. Common tin, however, is contaminated with traces of arsenic, copper, and lead, which are more liable to be acted upon by organic acids and vegetables containing sulphur, as onions, greens, &c. PEREIRA remarks that acid, fatty, saline, and even albuminous substances may occasion colic and vomiting by having remained for some time in tin vessels. Still, tin is unquestionably the safest and most wholesome metal that it is found practicable to employ in domestic economy.

611. **Zinc Vessels Objectionable.**—Zinc is rarely employed as a material for culinary vessels. In many cases it would be unsafe, as a poisonous oxide slowly forms upon its surface. It has been recommended for milk pans on the ground that milk would remain longer sweet in them, and hence, more cream arise. But whatever power of keeping milk sweet zinc possesses, it can only be caused by neutralizing the acid of milk with oxide of zinc, thus forming in the liquid a poisonous lactate of zinc.

612. **Behavior of Copper in contact with Food.**—This metal suffers very little change in dry air, but in a moist atmosphere oxygen unites with it, forming oxide of copper; and carbonic acid of the air, combining with that substance, forms carbonate of copper, of a green color. Copper is easily acted on by the acid of vinegar, forming *verdigris*, or the *acetate of copper*, which is an energetic poison. Other vegetable acids form poisonous salts with it in the same way. Common salt is decomposed by contact with metallic copper during oxidation, the poisonous *chloride* of copper being formed. All kinds of fatty and oily matter have the property of acting upon copper and generating poisonous combinations. Sugar also forms a compound with oxide of copper,—*the sacharate of copper.*

613. **Test.**—As the salts of copper are of a green color, vessels of this metal have a tendency to stain their contents green. They are sometimes employed purposely to deepen the green of pickles, &c., and cooks often throw a penny-piece into a pot of boiling greens to

intensify their color. A simple test for copper in solution is, to plunge into the suspected liquid a plate of polished iron, (a knife blade, for example,) when in a short time, (from five minutes to as many hours,) it will become coated with metallic copper. The solution ought to be only very slightly acid. Now, as acid, oil, or salt, is found in almost every article of diet, it is clear that this metal, unprotected, is quite unfit for vessels designed to hold food.

614. **Protection of Copper Utensils.**—Yet copper has several advantages as a material for culinary utensils. It is but slowly oxidized, and hence does not corrode deep, scale, become thin, and finally fall into holes as iron vessels are liable to do. Besides, copper is a better conductor of heat than iron or tin plate, and consequently heats more promptly and with less fuel, and as it wears long, and the metal when old bears a comparatively high price, its employment, in the long run, is unquestionably economical. Copper vessels ought never to be used, however, without being thoroughly protected by a coating of tin and when this begins to wear off they should be at once recoated, which the copper or tin-smith can do at any time. It has been stated that a small patch of tin upon the surface of a copper vessel would entirely prevent the oxidation of the latter by galvanic influence; but Mr. MITCHEL has shown by experiment that such is not the fact, and that the only safeguard is in covering completely the entire copper surface. Brass is an alloy of zinc and copper, and although less liable to oxidize, is nevertheless unsafe. Kettles of brass are often employed in preparing sauces, sweetmeats, &c., but this ought never to be done unless they are scrupulously clean and polished, and hot mixtures should not be allowed to cool or remain in them.

615. **Enamelled Ironware Vessels.**—It would seem that no one material possesses all the qualities desirable to form cooking vessels. Some of the metals are strong and resist heat; but, as we have seen, various kinds of food corrode them. Earthenware, on the contrary, if well made, resists chemical action, but is fractured by slight blows and the careless application of heat. An attempt has been made to combine the advantages of both by enamelling the interior of iron vessels with a kind of vitreous or earthenware glaze. Various cooking vessels, as saucepans, boilers, and the like, have been prepared in this manner, and answer an admirable purpose. Dr. URE remarks, I consider such a manufacture to be one of the greatest improvements recently introduced into domestic economy, such vessels being remarkably clean, salubrious, and adapted to the delicate culinary operations of boiling, stewing, making of jellies, preserves, &c.

616. **Earthenware Vessels—Glazing.**—Vessels of earthenware are in universal household use. They are made, as is well known, of clay and sand, of various degrees of purity, with other ingredients, forming a plastic mass, which is moulded into all required shapes, and hardened by baking in a hot furnace. The ware, as it thus comes from the baking process, is porous, and absorbs water. To give it a smooth, glossy, water-resisting surface, it is subjected to the operation of *glazing*. This is effected in two ways; first, when the stoneware has attained a very high temperature, a few handfuls of damp sea-salt are thrown into the furnace. The salt volatilizes, the vapor is decomposed, the hydrochloric acid escaping; while the soda, diffused over the surface of the ware, combines with its silica, and glosses over the pieces with a smooth, hard varnish. Another mode by which the desired artificial surface is given to earthenware, is by taking it from the fire when it has become sufficiently firm and stiff, immersing it in a prepared liquid, and restoring it again to the furnace, where by the action of heat a vitreous or glassy coating is formed.

617. **Earthenware Glaze containing Lead.**—The preparations employed for glazing common earthenware, are chiefly combinations of lead with the alkalies, producing vitreous or glassy compounds. It is known that lead enters largely into many kinds of glass; it imparts to them great brilliancy and beauty, but makes them soft, so that they are easily scratched, and liable to be attacked by strong chemical substances. Lead glaze upon earthenware is also subject to the same objection. It is tender and can be scraped off with a knife, so that the plates soon become marred and roughened. They also soon blacken, or darken, when in contact with sulphurized substances. Cooking eggs or fish in these vessels gives them a brownish tinge. If less lead be used, the glaze becomes less fusible, the process of applying it more difficult, and hence the ware more expensive. Lead glazing can be detected by its remarkably smooth, lustrous surface, resembling varnish; while the salt glaze, on the contrary, has less lustre, and the vessel has not so fine an appearance, all the asperities of the clay beneath being perfectly visible. Fatty matters, and the acids of fruits, exert a solvent action on oxide of lead combined in lead glaze, especially where the chemical energy is increased by a boiling temperature.

618. **Other defects of Earthenware Glaze.**—If a piece of earthenware be broken, we may observe upon the freshly fractured edge, the thin coating of glaze which has been fused on to the body of the ware. If the tongue be touched to the broken surface, it will adhere, showing the porous and absorbent nature of the material. Now it often hap-

pens that the shell of glaze and the body which it encloses, are not affected in the same way by changes of temperature. They expand and contract *unequally* when heated and cooled, the consequence being, that the glaze breaks or starts, and the surface of the plate, saucer, or vessel, becomes covered with a network of cracks. Ware in such a condition is said to be *crazed.* Through these cracks liquid organic matters are liable to be absorbed, which make the articles uncleanly and impure. Glaze that does not crack is often too soft. To determine this, drop a small quantity of ink upon it, and dry before the fire, and then wash it thoroughly; if the glaze be too soft, an indelible brown stain will remain.

619. **How Porcelain-ware is made.**—This is the purest and most perfect product of the plastic art. We are indebted for several suggestions concerning its processes to Messrs. HAVILAND, of this city, whose extensive establishment in France has afforded them a large experience in the porcelain manufacture. This ware was first made in China, and is still known as China-ware. But, after long and difficult experience, the manufacture has at length become so perfected in Europe as greatly to surpass the Chinese in elegance, and hence but little is now imported from that country. True porcelain consists of two essentially different constituents, one of which is an infusible, plastic, white clay, called *kaolin*, or China-clay, and the other an infusible but not plastic substance, called the *flux*, which is composed of the mineral felspar. Kaolin alone would afford a porous, opaque body; the flux, however, softens in the heat of the baking furnace, and penetrates as a vitreous or glassy matter the whole body of the clay, completely filling up the pores, and covering all the surface; it binds the whole together into a dense impenetrable mass. Porcelain-ware is translucent, or permits the partial passage of light, which is due to the clay body being saturated as it were with glass, as transparent paper is permeated with oil. The material is moulded with great care and nicety into the desired forms, and then, placed in cases of clay made expressly to hold and protect them, are put into the kiln or furnace, and subjected to an intense heat for 15 or 20 hours. The articles are then withdrawn and dipped into a glaze composed of felspar, of the same nature as the flux, and which never contains either lead or tin. The ware is then returned to the furnace and subjected to the most intense white heat that art can produce, for 10 or 20 hours longer. The glaze is thus melted into the flux, so that the porcelain has a uniform body, as we see when it is broken. There is no accurate mode of measuring the very high temperatures produced in these kilns, but by the method

adopted, the heat is estimated to run up to 21,000 degrees of the Fahrenheit scale. The color of porcelain is milk-white, without any tinge of blue. The qualities which give it pre-eminence among the clay wares, are the entire absence of porosity, the intimate union of the glaze with the mass, and the indestructibleness of the glazed surface under the knife, or when exposed to changes of temperature, and various chemical agencies. The production of the naked porcelain-ware in its present perfection, is one of the most signal triumphs of inventive ingenuity and perseverance, which the history of domestic improvement affords. But when we observe the beautiful and delicate colors with which porcelain is now ornamented, we are astonished at the resources of art. The paints or pigments with which exquisite pictures are made upon it, consist of *colored glass*, stained of various hues by metallic oxides. The *coloring materials* require to be fire-proof, as they are painted upon the ware, and then melted into the flux or glaze by the heat of the furnace.

620. **Repairing broken Porcelain.**—Various cements are in use for producing adhesion between fragments of broken porcelain and glass. A very strong cement for common earthenware is made by boiling slices of skim-milk cheese with water into a paste, and then grinding it with newly slaked lime in a mortar. White of egg will cause a quite strong adhesion, where the objects are not exposed to moisture. It is however improved by mixture with slaked lime. Shellac dissolved in alcohol or in a solution of borax, forms a pretty good cement. Various excellent cements are to be procured, ready prepared, of the dealers. In their anxiety to unite the fragments *strongly*, persons are apt to defeat their purpose by applying the cement too thickly, whereas the least possible quantity should be used, so as to bring the edges most closely together. This may be aided by heating the fragments to be joined.

VII.—PHYSIOLOGICAL EFFECTS OF FOOD.

1. Basis of the Demand for Aliment.

621. **Creation a Continuous Work.**—We are accustomed to conceive of the creation of man as a dim miraculous event of the most ancient time, half-forgetting that God's scheme of managing the living world is one of *perpetual* creation. Had our earth been formed of an eternal adamant, subject to no vicissitudes of change through all the cycles of duration, we might perhaps well refer to the act of bringing it into existence, as especially illustrative of creative power. But where all

is changing, transitory, and incessantly dissolving away, so that nothing remains immutable, but God's conception of being, which the whole universe is for ever hastening to realize, we cannot escape the conviction of his immediate, living, omnipresent, constructive agency. The truth is, we are hourly and momentarily created, and it is impossible to imagine in what respect the first act of formative power was more wonderful or glorious, or afforded any more conspicuous display of omnipotent wisdom, than that august procession of phenomena by which man, and the entire living world, are now and continually called into being. Those material atoms which are to-day interposed between us and destruction, are recent from chaos,—they were but yesterday formless dust of the earth, corroded and pulverized rocks, or fleeting and viewless gases of the air. These, through the vast enginery of astronomic systems, whose impulses of movement spring directly from the Almighty Will, have entered a world of organic order, are wrought into new states, and made capable of nourishing the animal body. The mingled gases and mineral dust, have become vital aliment. The test-miracle which the Tempter of old demanded as evidence of Godlike Power, is disclosed to the eye of science, as a result of natural laws, for in the most literal sense, "stones are made bread."

622. **Our Systems capable of being understood.**—That it was designed for us to understand what goes on within the body, we are not at liberty to doubt. Instead of being the theatre of a mysterious power which defies investigation, we find the living system acting under allegiance to invariable laws, and entirely amenable to investigation. The whole course of physiological discovery has consisted in showing that the human constitution is an embodiment and illustration of reason. The victory of research is to *understand* a thing; that is, to bring it into agreement with reason. The mechanism of the eye was a mystery, until its optical adaptations and purposes were discovered; that is, the *reason* of its construction. The heart was an object of mere curious wonder and superstitious speculation, until the circulation was discovered, when the *reasonable uses* of its parts were at once understood. The whole scope and drift of past inquiry, and all the considerations which cluster around the subject, lead us to expect and demand a rational explanation of living processes. "Not many years ago, the most acute and distinguished physicans regarded the stomach as the abode of a conjurer; who, if respectfully treated, and in good humor, can change thistles, hay, roots, fruits, and seeds, into blood and flesh; but when angry, despises, or spoils the best

food." Chemistry has dispelled these crude fancies, and enabled us to *understand* how such marvellous transformations occur. We are getting daily clews to the profounder secrets of the organism; knowledge is here as rapidly progressive as in any other department of science. In this connection Dr. DRAPER remarks, "Since it is given us to know our own existence, and be conscious of our own individuality, we may rest assured that we have what is in reality a far more wonderful power, the capacity of comprehending all the conditions of our life. God has formed our understanding to grasp all these things. For my own part, I have no sympathy with those who say of this or that physiological problem, it is above our reason. My faith in the power of the intellect of man, is profound. Far from supposing that there are many things in the structure and functions of the body which we can never comprehend, I believe there is nothing in it that we shall not at last explain. Then, and not till then, will man be a perfect monument of the wisdom and power of his Maker, a created being knowing his own existence, and capable of explaining it."

623. **The living System a theatre of change.**—The body of the grown man presents to us the same unaltered aspect of form and size, for long periods of time. With the exception of furrows deepening in the countenance, an adult man may seem hardly to alter for half a hundred years. But this appearance is altogether illusory; for with apparent bodily identity, there has really been an active and rapid change, daily and nightly, hourly and momently, an incessant waste and renewal of all the corporeal parts. A waterfall is permanent, and may present the same aspect of identity, and unchangeableness from generation to generation; but who does not know that it is certainly made up of particles in a state of swift transition; the cataract is only a *form* resulting from the definite course which the changing particles pursue. The flame of a lamp presents to us for a long time the same appearance; but its constancy of aspect is caused by a ceaseless change in the place and condition of the chemical atoms which carry on combustion. Just so with man; he appears an unchanged being endowed with permanent attributes of power and activity, but he is really only an unvarying *form*, whose constituent particles are for ever changing. As the roar, spray, and mechanical power of the falling water are due to changes among the aqueous particles; and the heat and light of the flame are due to changes among combustible atoms; so man's endowments of bodily activity, susceptibility, and force, originate in atomic transformations taking place in his

system. As each part is brought into action, its particles perish and are replaced by others; and thus destruction and renovation in the vital economy are indissolubly connected, and proceed together. It is said, with reference to the casualties to which man is every where exposed, that "in the midst of life we are in death," but physiologically, this is a still profounder truth; we begin to die as soon as we begin to live.

624. **Rate at which the vital changes proceed.**—But very few persons have any correct conception of the rate at which change goes on in their bodies. The average amount of matter taken into the system daily, under given circumstances, has been determined with a considerable degree of precision. From the army and navy diet-scales of France and England, which of course are based upon the recognized necessities of large numbers of men in active life, it is found that about 2¼ lbs. avoirdupois of dry food per day are required for each individual; of this about three-quarters are vegetable and the rest animal. Assuming a standard of 140 lbs. as the weight of the body, the amount of oxygen consumed daily is nearly 2⅕ lbs., which results from breathing about 25 or 30 hogsheads of air; the quantity of water is nearly 4$\frac{1}{10}$ lbs. for the same time. The weight of the entire blood of a full-grown man varies from 20 to 30 pounds; of this, the lungs, in a state of health, contain about half a pound. The heart beats, on an average, 60 or 70 times in a minute. Every beat sends forward two ounces of the fluid. It rushes on, at the rate of 150 ft. in a minute, the whole blood passing through the lungs every two minutes and a half, or twenty times in an hour. In periods of great exertion the rapidity with which the blood flows is much increased, so that the whole of it sometimes circulates in less than a single minute.—(Johnston.) According to these data, all the blood in the body, travels through the circulatory route 600 or 700 times in a day, or a total movement through the heart of 10,000 or 12,000 lbs. of blood in 24 hours. To assist in carrying forward the several bodily changes, various juices are poured out each day, according to the latest estimates, as follows: gastric juice, 14 to 16 lbs.; bile, 3 to 4 lbs.; pancreatic juice, ½ lb.; intestinal juice, ½ lb.—(Dr. Chambers.) At the same time there escapes from the lungs nearly 2 lbs. of *carbonic acid* and 1¼ of *watery vapor.* The *skin* loses by perspiration 2½ lbs. of water, and there escape in other directions about 2¼ lbs. of matter. In the course of a year, the amount of solid food consumed is upwards of 800 lbs.; the quantity of oxygen is about the same, and that of water taken in various forms, is estimated at 1,500 lbs., or all together a ton and a

half of matter, solid, liquid, and gaseous, is ingested annually. We thus see that the adult, of a half a century, has shifted the substance of his corporeal being more than a thousand times.

625. **A striking illustration of these changes.**—Let us take a signal example, which, although not falling within the limits of ordinary experience, yet actually occurred in the course of nature. THOMAS PARR, of England, lived to the age of 152 years. If we take the twelve years of his childhood, and double them over upon the succeeding twelve years of his youth, we shall have 140 years of adult life, or twice the common allotment of man. Applying to his case then the established physiological constants, we get the following startling results of the amount of possible change in matter produced in the lifetime of a single man. He drank upwards of a hundred tons of water, ate nearly sixty tons of solid food, and absorbed from the air one hundred and twelve thousand lbs. of oxygen gas to act upon that food. There are fifteen lbs. weight of air resting upon every square inch of the earth's surface; of this one-fifth is oxygen, there being therefore 3 lbs. of oxygen over every square inch of the earth, extending to the top of the atmosphere. The daily consumption by respiration is 2 lbs. PARR, therefore, consumed all the oxygen over a surface of 236 square feet of ground to the very summit of the earth's atmosphere, and generated noxious gases enough to contaminate and render unfit for breathing ten times that space, or poison a column of air 45 miles high, having a base of nearly 2,400 square feet. If we may indulge in a somewhat violent supposition that the whole blood which was actually driven through his heart during that long period could have been accumulated and measured as one mass, by forming a procession of vehicles, each taking a ton and occupying two rods of space, such a procession would have attained the enormous length of 2,000 miles.

626. **Relation between Waste and Supply.**—Such is the ground of our daily requirement for food. The annual supply of 3,000 lbs. of matter to the body is demanded, because in the yearly exercise of its powers and functions 3,000 lbs. of matter have been used up or spent. It cannot be maintained for a moment that the bodily system possesses any power of producing or creating a single particle of the matter which it uses; it must receive every thing from without, and maintain its uniform condition of weight by striking an exact balance between waste and supply, receipt and expenditure. There are two periods in the natural life of man when the balance between these antagonizing forces is overturned; in *infancy, childhood* and *youth*, the reception

of matter prevails over its loss, and the body steadily augments in weight; in *old age* reparation does not keep pace with decay, and the bodily weight gradually declines. In the intervening period of adult life these antagonizing forces are maintained with but little variation in a state of constant equilibrium. In all the deepest recesses of the body, in every springing muscle, and conducting nerve and connecting tissue, and even the thinking brain, myriads of atoms are continually passing into the condition of death, while by the profoundest law of physiological life an exactly equal number are constantly introduced to replace them, each of its proper kind and in its appropriate place.

626. **Practical inference from these facts.**—As thus the living being is the result and representative of change on a prodigious scale, the question of the course, rate, and regulation of those changes must be controlling and fundamental. Matter is introduced into the system in one condition and escapes from it in another; the change (*metamorphosis*) that it has undergone is oxidation, or a true burning. The solid aliment is all combustible, oxygen is the agent which burns or destroys the food by uniting with it, and water the medium which brings them into proper relation to act on one another. Hence the life, activity, and multiform endowments of the organism, originate in the chemical action and reaction of prepared matter, borrowed temporarily from the outward world to be quickly restored to it again. And as the supply of nutritive matter is effected through our own voluntary agency; as we select, mingle and prepare the nutritive materials, and control the times, frequency, quantity and condition in which they shall be taken, and influence their physiological results in numberless ways, it is clear that our practice, whatever it may be, must exert a direct and powerful influence upon the whole being; its states of feeling, conditions of action, health, and disease. It is desirable therefore to gain the fullest possible understanding of the subject.

627. **Beneficent use of Hunger and Thirst.**—It will be seen from the nature of the case, that the necessities of the system for matter from without, are pressing and momentous. If the inflowing tide of gases be arrested but for a few moments, suffocation and death follow. If the liquid and solid aliments be withheld, indescribable agonies shortly ensue, and in a few days the extinction of life. There is, therefore, an irresistible life-demand for the supply of nutriment which cannot be put off upon peril of existence, while the cost of nutritive matter is laborious struggle and exertion, both of body and mind. Now it is plain, that if in the plan of our being the bodily requirement for food were left to the determination of reason, the purposes of nature would

be liable to continual defeat from indolence, carelessness or urgency of occupations. The Divine Architect has therefore wisely intrenched in the system two monitors, *hunger* and *thirst*, which are independent of reason or will, cannot be dislodged while life lasts, and whose duty it is to proclaim that further nourishment is required for bodily support. And beside the sensations of hunger and thirst, imperative as they are, there is attached to their proper indulgence a degree of pleasure which never fails to insure attention to their demands. In what hunger and thirst consist, what state of the stomach or vessels produces them, or how the general nutritive wants of the system get expressed in feeling or sensation, we do not know; several explanations have been offered upon this point, but they are all unsatisfactory.

628. Impelled by the demands of the constitution food is procured, and in several ways, which have been described, prepared for use. When taken into the system it is subject to various changes in a certain natural and successive order, which will next be noticed.

2. First Stage of Digestion—Changes of Food in the Mouth.

629. **The great object of Digestion.**—The prepared food upon our tables is in the form of crude, unmixed, and chiefly solid masses. Various vegetables, breads, meats, butter, each with its peculiar constituents and properties, are ready for use. Their physiological purpose is to make blood, the source upon which the whole system draws for whatever it requires. The blood contains every thing necessary to form all the parts, and produce all the peculiar liquids or secretions of the body. It circulates rapidly through every portion of the system, bearing all the constituents that can be required, while each part is endowed with the special power of withdrawing from the current as it passes along, just those particular constituents that it may require; compounds of lime for bones and teeth, sulphurized compounds for the muscles, and phosphorized for the nerves, while various parts separate the liquids of secretion—the glands of the mouth attracting out the substances necessary to form saliva, those of the eyes the elements of tears, the coats of the stomach, gastric juice, and the liver, bile. The blood is a magazine of materials comprehensive enough for every want of the body, and all brought to a perfectly fluid condition, so as to flow with facility through the minutest vessels. Now, it is obvious that the food before us must be profoundly changed before it can become blood. No one element of diet contains all the necessary ma-

terials for this purpose; the various articles must, therefore, be mixed. Some of the elements of food are incapable of forming blood; these require to be separated, and the entire nutritive portion brought into a state of perfect liquidity. To effect these important changes in food is the great purpose of *digestion*, which presents itself to our consideration in three distinct stages, commencing with transformations produced in the mouth.

630. **Reducing Mechanism of the Mouth.**—The food, liquefied or softened, or with its texture relaxed, loosened, or made spongy by culinary methods, is reduced to small pieces by table instruments, and thus transferred to the mouth. An ingenious cutting and grinding mechanism here awaits it, to complete the mechanical operation of crushing and reducing. It consists of a double system of teeth, planted firmly in the jaws, and made to work against each other by a set of powerful muscles. The teeth are so shaped and placed as to combine cutting, crushing and grinding, through vertical and side movements of the lower jaw. The teeth are 32 in number, and their differences are illustrated by Fig. 113, which represents half the lower jaw. *A* shows two of the front or cutting teeth, called *incisors*; *B* the *cuspid*, *canine*, or dog tooth, so called from being large in the dog and carnivorous animals, and used by them to seize and tear their food; *C* the *bicuspids* or *double-speared*, from their resemblance to a double-headed canine tooth; and *D* the *molars*, double-rooted, with broad, irregular, grinding surfaces.*

FIG. 113.

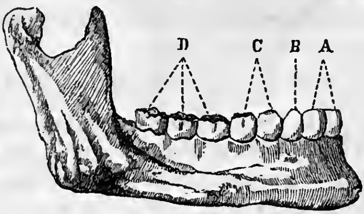


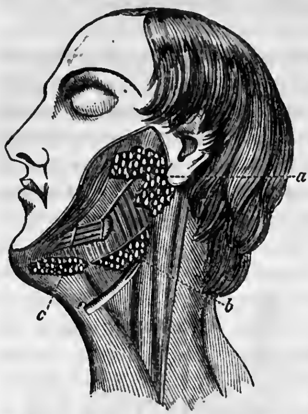
Illustration of the different kinds of Teeth.

631. **Conditions of the flow of Saliva.**—But no amount of mechanical action alone will convert solid aliment into the fluid state. If the food is to be dissolved, there must be a *solvent* or liquid to bring about the solution. It is the office of the *saliva* or *spittle* to commence this work. The saliva is separated from the blood and poured into the mouth by three pairs of glands (Fig. 114). The rate at which it is secreted varies at different times and under different circumstances. The sight, or even the thought of dinner may fill the mouth with it, while continued mental attention to other subjects, or a state of anxi-

*"In Latin, *cuspis* signifies the point of a spear; *canis*, dog; *mola*, a mill; *incisor* anything which cuts."

ety, will dry it up. The movements of the mouth, as in speaking, reading, or singing, excite its flow, but it is most copiously furnished at times of eating, by the contact and pressure of food during mastication. Hence, the glands on that side of the mouth which is most used in mastication, secrete more than the others. The nature of the food causes the quantity furnished at meals to vary exceedingly; hard, dry aliments provoking a much greater discharge than those which are moist and soft. It streams out abundantly under the stimulation of spices, and continues to flow after the meal is concluded; the secretion also goes on during sleep.

FIG. 114.



Salivary glands; *a* parotid, *b* submaxillary, *c* sublingual.

632. **Properties.**—The saliva is a clear, slightly bluish, glairy juice, readily frothing. It contains less than one per cent. of saline matter, and in health is always alkaline. It contains also an organic principle named *ptyalin*, an albuminous substance which acts as a strong ferment. The tartar which collects on the teeth is the residue left by evaporation of the water of the saliva, and consists of earthy salts, cemented together by animal matter. The salivary juice of the mouth is, however, a mixture of three different salivas poured out by three pairs of glands. Parotid saliva is thin and watery, so as to be readily incorporated with the food by the teeth; it also contains much lime. Submaxillary saliva is so thick and glutinous that it may be readily drawn out into threads. It is supposed to facilitate swallowing by affording a sort of anti-friction coating to the masticated food. The sublingual saliva is more limpid, resembling the parotid.

633. **Uses of Saliva.**—Saliva serves not only to moisten and lubricate the mouth, and wet the aliment, so that it may assume a pasty or pulpy condition, but it is an indispensable medium for the sense of taste, as every thing is tasteless which the saliva cannot dissolve. By its frothy quality it embroils globules of air, and thus serves to convey oxygen into the stomach, where it probably plays a part in promoting the transformations. But beyond these important effects, the saliva actually begins the operation of digestion in the mouth. If a little

pure starch be chewed for a short time, it will become sweet; a portion of it has undergone a chemical transformation, and been converted into sugar. By its joint alkaline and fermentative powers, saliva produces an almost instantaneous effect upon starch, changing it first into sugar, and in a little longer time converting the sugar into lactic acid. This important change seems to be effected, not by any one of the salivary secretions, but is due to their combined action. Saliva exerts no solvent influence upon the nitrogenous aliments. It will thus be noticed that the first chemical attack, at the very threshold of the digestive passage, is made upon that alimentary principle which abounds most of all in our food (382). We furthermore draw a practical inference opposed to the current opinion which assumes that animal food, from its tough, fibrous nature, needs more mastication than vegetable. Meat and albuminous substances require to be thoroughly disunited and subdivided in order that each particle may be brought into contact with the secreting membrane of the stomach, while bread, and substances which abound in starch, have not only to be reduced fine, but to be well imbued with the salivary liquid. In animal food, it is possible to supply the place of mastication by the use of implements in the kitchen and at the table; but culinary science cannot compound an artificial saliva to be mixed with starchy food, so as to save the trouble of chewing it. The changing of this substance from a solid to a liquid form, as in gruel and sago slops, so that they are swallowed without being delayed in the mouth and mingled with its secretions, is unfavorable to digestion, especially if the stomach be not vigorous. The best condition in which starch can be taken is where the outer membrane has been ruptured by heat, and the mass made light, as in well-baked bread and mealy potatoes (532).

634. **Importance of thorough Mastication.**—The mechanism of insalivation has been inserted in the mouth for a definite and important purpose, and as the act of mastication is under the control of the will, it is very easy to defeat that purpose. If the food be imperfectly chewed, and hastily swallowed, or as the phrase goes, 'bolted,' the aliment passes into the stomach crude and ill-prepared, and the whole digestive function is just so far imperfect and enfeebled. It is of much consequence that meals should not be precipitated, but that proper time should be allowed to perform that portion of the digestive operation, which falls so directly under voluntary control. Besides thoughtlessness, and business pressure which pleads want of time, there is another cause of inattention to this matter which deserves notice. Many persons have placed themselves in such a false relation to nature, as

to imagine that they exalt the spiritual attributes of their being by casting *contempt upon the physical.* Such are inclined to regard the act of eating as a very animal and materializing operation, and any considerations of the way it should be conducted, are apt to weigh but lightly upon their minds. This view is false, and leads to consequences practically mischievous. Dr. COMBE remarks,—"Due mastication being thus essential to healthy digestion, the Creator, as if to insure its being adequately performed, has kindly so arranged that the very act of mastication should lead to the gratification of taste—the mouth being the seat of that sensation. That this gratification of taste was intended, becomes obvious when we reflect that even in eating, nature makes it our interest to give attention to the process in which we are for the time engaged. It is well known, for example, that when food is presented to a hungry man, whose mind is concentrated on the indulgence of his appetite, the saliva begins to flow unbidden, and what he eats is consumed with a peculiar relish. Whereas, if food be presented to an individual who has fasted equally long, but whose soul is absorbed in some great undertaking or deep emotion, it will be swallowed almost without mastication, and without sufficient admixture with the saliva—now deficient in quantity—and consequently lie on the stomach for hours unchanged. A certain degree of attention to taste and the pleasures of appetite is, therefore, both reasonable and beneficial; and it is only when these are *abused* that we oppose the intention of nature."

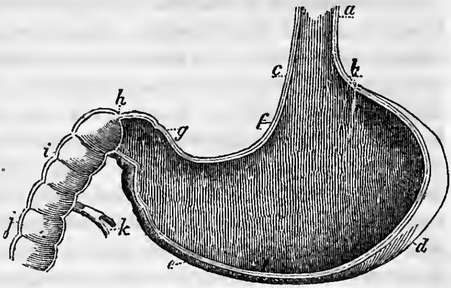
635. **Effect of profuse Spitting.**—The salivary juices are parts of a great water circulation of secretion and absorption. They are poured into the mouth, *not to be cast out*, but to do a specific work, and then pass into the stomach and be again absorbed. If they are habitually ejected by spitting, the object of nature is contravened, and the system drained of that which it was not intended to lose. In such case the order of bodily functions is reversed, and the mouth is converted into an organ of excretion. It is the office of the kidneys and urinary ducts to convey away a large part of the superfluous water, and all the waste salts that require to be expelled from the body; but if a drain be established at the mouth, the effect is to relieve those parts of a portion of their labor. "When the impure habit of profuse spitting is indulged in, it is interesting to remark the reflected effect which takes place in the reduced quantity of the urinal excretion, and an instinctive desire for water, a kind of perpetual thirst. It is probable that, under these disgusting circumstances, the percentage amount of saline substances in the saliva is increased, and that, so far as that

class of bodies is concerned, the salivary glands act vicariously for the kidneys, and the mouth is thus partially converted into a urinary aqueduct."—(Dr. DRAPER.)

3. SECOND STAGE OF DIGESTION—CHANGE OF FOOD IN THE STOMACH.

636. **Figure and Dimensions of the Organ.**—Having undergone more or less perfectly the changes which appertain to the mouth, the food is swallowed, and passing down the esophagus, or gullet, enters the stomach. This organ is a pouch-shaped enlargement of the digestive tube, having the form shown in Fig. 115. The larger extremity is situated at the right side of the body, and its lesser end at the left. That portion where the esophagus enters it, is termed the cardiac region (because it is in the vicinity of the *kear* or *heart*); the other extremity, where the contents of the stomach escape into the intestine, is known as the pyloric region (from *pylorus*, a gate-keeper). The capacity of the human stomach of course varies considerably, but on an average, it will hold when moderately distended about three pints. As a general rule, it is larger among those who live upon coarse, bulky diet. In different animals the size of the stomach varies exceedingly, according to the *concentration* of the food upon which they live. Thus in the flesh-eating animals it is very small, only a slight enlargement of the esophagal tube; while in those which feed upon herbage, it is distended into an enormous cavity, or rather into several, as in the *ruminants*, cows, sheep, &c.

FIG. 115.



Section of the human stomach: *a* esophagus; *b c* cardiac orifice; *d e* greater curvature; *f g* lesser curvature; *h* pyloric orifice; *i j* duodenum; *k* bile duct.

637. **Layers of the Stomach.**—The walls of the stomach consist of three membranous coats. The outer layer is a smooth, glistening, whitish membrane (*serous membrane*), lining the abdomen, and covering all the internal organs, which it strengthens, and by its smoothness and constant moisture, permits them to move upon each other without irritation. The middle coat consists of two layers of muscular fibres or bands, one of which runs lengthways, and the other crossways,

or around the organ. By means of these muscles the stomach may contract its dimensions in all directions, so as to adapt its capacity to the amount of its contents. They also give to the organ its constant motion during digestion. The third layer of the stomach (*mucous membrane*) lines its internal surface. It is a soft, velvet-like membrane, of a pale pink color, in health, and of much greater extent than the outer coats, by which it is thrown into folds or wrinkles. It is constantly covered with a thin, transparent, viscid mucus.

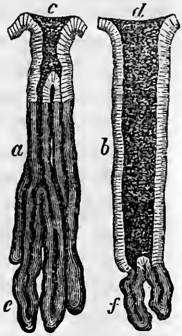
638. **Motions of the Stomach.**—The food upon which operations have been commenced in the mouth, is passed into the stomach, but it is not permitted to rest. By the successive contraction and relaxation of its muscular bands, the stomach imparts to its contents a constant churning, or revolving motion. In the celebrated case of St. Martin, a Canadian soldier, whose stomach was opened by a gunshot wound in the side, and healed up leaving a permanent orifice (*gastric fistula*), Dr. Beaumont made numerous observations of digestive phenomena. He thus describes the movements of food within the organ. "After passing the esophagal ring it moves from right to left along the small arch; then through the large curvature from left to right. The bolus (*swallowed mouthful*), as it enters the cardiac, turns to the left, descends into the splenic extremity (*large extremity near the spleen*), and follows the great curvature towards the pyloric end. It then returns in the course of the smaller curvature, performing similar revolutions. These revolutions are completed in from one to three minutes. They are slower at first, than after digestion is considerably advanced." The motion is not absolutely constant, but continues for a few minutes at a time. If the food remains in the stomach three hours it travels round and round through this circuit two or three hundred times:—to what purpose?

639. **Minute arrangements for Stomach Digestion.**—Before considering what takes place in the stomach, we must have a closer view of its mechanism. The lining layer of this organ is curiously and admirably constructed, though it requires the microscope to see it. Magnified about 70 diameters the mucous membrane exhibits the honeycombed appearance seen in Fig. 116. Into these reticulated spaces, there open little cup-shaped cavities called *stomach follicles*, which are about 1·200 of an inch in diameter. They are closely packed together in the mucous membrane, so that when it is cut through, and viewed with the microscope, it looks

Fig. 116.

like palisading, or like little flasks or test-tubes close packed and upright; many thousands of these upright cylindrical cavities being set in a square inch of surface. They are of different depths in different parts of the stomach, and they terminate at the bottom in minute closed tubes. The arrangement has been likened to a little glove, the hand of which opens into the stomach, while the fingers are buried in the tissue beneath. Fig. 117, represents the secreting follicles in the stomach of a dog after twelve hours' abstinence; *a*, from the middle region of the stomach; *b*, from near the pylorus; *c d*, the mouths opening upon the surface, *e f*, the closed tubes imbedded in the membrane below. The walls of these cavities are webbed over with a tissue of most delicate bloodvessels, carrying streams of blood —a network of veins surrounds their outlets upon the surface of the membrane, while nerves innumerable pervade the whole arrangement.

Fig. 117.



640. **Use of these little pocket-shaped vessels.**—What, now, is the purpose served by these interesting little contrivances? It is to separate from the blood the digestive fluid of the stomach. But they do not effect this directly; another agency,—that of cells (496),—is called into play. The gastric juice does not simply ooze or distil from the blood into the stomach. It is manufactured by a determinate process. "For each minutest microscopic drop of it, a cell of complex structure must be developed, grow, burst and be dissolved." At the bottom of the cavities, in the little tubular roots, the seeds or germs of cells arise in immense numbers. Recurring to the simile of the glove, within each finger, at the tip and upon its sides, the cells take origin, and, nourished by the blood, multiply and swell until they are driven up in crowds into the hand or larger cavity, and having reached their full maturity, are pushed out at the surface, burst, and deliver their contents into the stomach.

641. **The periodic supply of Food.**—The digestive principles are thus a product of cell-action, and into their preparation there enters the element of *time*. Though short-lived, a certain period must elapse for their production. During digestion the cells are perfected in incredible numbers, and yield large amounts of fluid. During fasting, no full-grown cells escape; the tubes collapse, and an opportunity is allowed for the production of a new stock of germs or cell-grains. If this be so, it must follow that we cannot with impunity interfere with

that which seems a natural rule, of allowing certain intervals between the several times of eating. Every act of digestion involves the consumption of some of these cells; on every contact of food some must quickly perfect themselves, and yield up their contents; and without doubt, the design of that periodical taking of food, which is natural to our race, is, that in the intervals, there may be time for the production of the cells that are to be consumed in the next succeeding acts of digestion. We can, indeed, state no constant rule as to the time required for such constructions; it probably varies according to age, the kind of food, the general activity or indolence of life, and above all, according to habit; but it may be certainly held, that when the times are set, they cannot with impunity be often interfered with; and as certainly, that continual or irregular eating is wholly contrary to the economy of the human stomach.—(PAGET.)

643. **Properties of Gastric Juice.**—The digestive juice of the stomach is a colorless, inodorous, slightly viscid fluid, which when removed from the organ, retains its active properties for a long time, if kept excluded from the air. A boiling heat destroys its activity, but freezing does not. In a healthy state, it is always distinctly sour, which is caused by an uncombined acid, usually the hydrochloric, but sometimes lactic acid. With its acid principle, the gastric juice also contains a peculiar albuminous body called 'pepsin' or 'ferment substance.' If the juice be evaporated to dryness, this pepsin constitutes three-fourths of the solid residue. As the food is rolled round in the stomach, it is incorporated with this juice, and changes gradually to a pulpy semi-fluid mass. Digestion is fully under way in an hour after the meal is taken, and is usually finished in about four.

644. **Limit of Stomach Digestion.**—Recent physiological investigations have exploded the opinion long entertained, that the stomach is the exclusive or principal seat of digestive changes. In tracing the properties of foods, we had occasion to divide them into two great classes based upon fundamental differences in chemical composition—the nitrogenous and the non-nitrogenous aliments. We find this distinction recognized by nature in arranging her plan of digestion. So different are these two kinds of aliments that they require totally different agents to dissolve them,—nay, solvent fluids of entirely opposite characters. We have seen that digestion began in the mouth with an alkaline liquid, and took effect only upon the non-nitrogenous principles. Upon proceeding to the stomach we find new conditions—an acid liquid replaces the alkaline—the changes that commenced in the mouth are partially or totally suspended, the non-nitrogenous com-

pounds remain unaltered, the gastric fluid taking effect only upon nitrogenous substances.

645. **Action of the Acid and Ferment.**—If coagulated white of egg be placed in water acidulated with hydrochloric acid, no solvent action takes place at common temperatures for a long time. If the temperature be raised to 150°, a slow dissolving effect begins, which is much increased at the boiling heat. But if a little 'pepsin' be added to the liquid the solution goes on actively, so that the pepsin, as it were, replaces the effect of a high temperature. An ounce of water mixed with twelve drops of hydrochloric acid and one grain of pepsin, will completely dissolve the white of an egg in two hours at the temperature of the stomach (100°). It acts in the same manner on cheese, flesh, vegetable gluten, and the whole nitrogenous group, changing them to the liquid form. These are the results of an *artificial* gastric juice, but they are exactly the same *in kind* as those which take place in the stomach. Drs. Bidder and Schmidt, whose researches upon digestion are the most recent and extensive, have shown that gastric juice withdrawn from the stomach and placed in vials, produces upon food precisely the same alterations as occur in the stomach, only much more slowly. In consequence of the motions of the stomach turning the aliment round and round, and the flow of the secretions which constantly washes away the dissolved parts and exposes fresh surfaces, the action proceeds about five times faster within the body than without, but the nature of the results is identical.

646. **What is the Digestive Ferment Substance?**—There has been much controversy about pepsin; what is it? A substance in the gastric fluid discovered by Schwan a few years ago, and supposed to be a peculiar principle specially prepared for digestive purposes. It may be obtained from gastric juice, or by soaking the membrane of a calf's stomach (*rennet*). When proper means are taken to separate and dry it, it appears as a yellow gummy mass. Its potency for digestive purposes was proved by Wasmann, who showed that a solution containing only 1-60,000th part, if slightly acidulated, dissolves coagulated albumen in six or eight hours. Liebig is, however, disinclined to regard pepsin as a peculiar digestive agent. He maintains that the fermentative change of digestion is due to minute parts of the mucous membrane of the stomach, separated and in a state of decomposition. The surface of that membrane is lined with what is called *epithelium*, composed of exceedingly thin filmy cells; and physiologists have discovered, that during digestion it separates completely from the other layers of the

membrane. This epithelium, acted on by the oxygen swallowed in the frothy saliva, excites the digestive fermentation attributed to pepsin. It may be remarked that this stomach fermentation cannot change the starch of food into alcohol and carbonic acid, nor give rise to gases, although in morbid conditions of the organ other fermentations may arise in the alimentary mass.

647. **Gastric Digestion something more than Solution.**—It was formerly thought that digestion was simply solution, or change of alimentary matter to the liquid state; but late investigations inform us that nutritive substances are more than dissolved, they are really altered in properties. The nitrogenous matters are not only dissolved, but are so modified as to *remain* dissolved. In ordinary solution a solid body is changed to a liquid by the action of another liquid or solvent; but when the solvent is removed the dissolved substance again resumes its solid condition. Not so, however, in gastric digestion; the digestive fluid dissolves albumen, fibrin, casein; but as it cannot accompany them to maintain them in this state, it impresses upon them a still further change, by which they continue soluble. Casein in milk, and liquid albumen are already dissolved when swallowed; but they are not digested, and the first act of the stomach is to coagulate or solidify both. They are then dissolved again, and so altered as to retain the new condition under circumstances which would have been before impossible; while their capability of being absorbed, so as to pass into the blood, is greatly increased. The term '*peptone*' has been given to nitrogenous matters changed in this way; thus albumen produces an albumen-peptone; fibrin, a fibrin-peptone; and casein, a casein-peptone,—substances which have lost the power of coagulating or setting into a jelly as they did when dissolved before. It has been found that oil plays a part in the changes by which the peptones are produced; so that, although oily matters are certainly not themselves digested in the stomach, they are made to serve a useful purpose in passing through it. The nitrogenous matters are not chemically altered, except perhaps by combining with water.

648. **Action of Saliva in the Stomach.**—The alkaline saliva attacks the sugar and starch in the mouth, and has the power of rapidly changing the starch into sugar, and that into lactic acid. But the food tarries only a few moments in the mouth; charged with its alkaline solvent, it descends into the acid region of the stomach. But acids and alkalies cannot get on together. They either kill each other, or if one is the strongest or most abundant, it destroys the other, though not without injury to itself. Hence, whenever the saliva

and gastric juice come into contact, the former will be neutralized by the excess of the latter, and a stop put to its action. Yet this does not occur instantaneously, as the food is swallowed. The effect of the gastric juice is superficial, acting at first upon the food where it comes in contact with the bedewed coats of the stomach, while the saliva, incorporated within, is allowed a little time for action. In this limited sense there may be two digestions going on in the stomach, although gastric digestion speedily overpowers and suspends the salivary. It is interesting to remark that lactic acid may replace hydrochloric in stomach digestion, and that if from any cause the latter is not supplied in due quantity, the saliva, acting upon the contents of the stomach, will generate the required substitute.

649. **Quantity of Gastric Juice secreted.**—There has been, and indeed there still is, much doubt upon this point; but it is now generally conceded that former estimates ranged much too low. The hourly destruction of fibrin throughout the system, in average muscular action, has been assumed at 62 grains, and it has been found that 20 parts of gastric juice are needed to dissolve one part of dry nitrogenous matter. To digest this quantity only, some 60 or 70 ounces of the fluid would be required. It is obvious that the natural quantity must much exceed this, as a considerable portion will be neutralized by the saliva, and much inevitably escapes into the intestines. But observation indicates quantities greatly higher than any calculated results. In the case of dogs, BIDDER and SCHMIDT found from experiment the proportion to be one-tenth of their weight. This proportion applied to man would give a daily secretion of 14 lbs. Dr. GRUNEWALDT has however quite recently had an opportunity of determining the quantity yielded by the human body, in the case of a stout, healthy peasant girl, weighing 120 lbs., who had a fistulous opening in her stomach, from childhood, that did not in the least degree interfere with her general health. His experiments gave the astonishing result of 31 lbs. of the gastric secretion in 24 hours, or one-fourth the weight of the body. Making every possible allowance for error in these investigations, we must conclude that the quantity of digestive fluid poured out each day must, at any rate, be very large.

650. **Digestibility of Foods.**—By this we understand their capability of yielding to the action of the digestive forces, the joint result of several distinct chemical agents fitted to act upon special constituents of the food, and brought into play throughout the whole alimentary tract. Digestion is therefore an affair of many conditions, and its results are by no means capable of being so simply stated as has been

formerly believed. What goes forward in the *stomach*, although of great importance, affords but a partial view of the whole operation. Dr. BEAUMONT made an admirable series of observations upon this organ, and did much to advance the inquiry. Yet the value of his observations was diminished by the imperfect knowledge of his time, for we see him constantly misled by the conviction that there is but one digestive agent, the gastric juice, and but one digestion, that in the stomach. We speak of *his time*, as if he might have lived long ago. Measuring the time by the course of investigation, he did live long ago. The history of science has a chronology of deeds, and marks off time by what has been accomplished. DUFAY, announcing the first laws of electricity, in 1737, stood much nearer THALES, of ancient Greece, rubbing his piece of amber, than to Prof. MORSE, patenting the electro-magnetic telegraph, in 1837. Within a quarter of a century, organic and animal chemistry have risen to the position of separate and independent branches of science; and it is hardly an exaggeration to say that more has been done to elucidate the subject of digestion in the 30 years that have elapsed since Dr. BEAUMONT began his experiments, than was accomplished by all the physiologists who preceded him, though we are far enough yet from any thing like a clearing up of the subject. Regarding digestion comprehensively, as the blood-forming function, we are to take into account not only the solubility of aliments, but their conformability to the blood. If two substances are dissolved with equal ease, that will be the more digestible which has the greatest similarity to some constituent of the blood. Gum, for example, is much more easily dissolved than fat, yet the latter is a constant constituent of blood, while the former is never found there. Gum, to be made available, must pass through a series of transformations,—sugar, lactic acid, butyric acid, while fat passes into the circulation without decomposition. "If the conformity of two alimentary principles with the constituents of the blood is equal, the more soluble is the more digestible. Soluble albumen and fibrin stand equally near to the blood, both being contained in it; as the soluble albumen is however more readily dissolved in the digestive juices than fibrin, the digestion of the latter is more difficult." We thus see that the digestibility of foods is not the mere matter of the *time of solution* in the stomach that has been generally supposed, but involves much more. Meanwhile, Dr. BEAUMONT's statements of the periods which various alimentary substances require to break down into chyme in the stomach, may be serviceable, if received with due restrictions. We subjoin an abstract.

MEAN TIMES OF CHYMIFICATION OF FOOD.

Articles.	Preparation.	Time.	Articles.	Preparation.	Time.
		h. m.			h. m.
Rice	Boiled	1 —	Pork, recently salted	Raw	3 —
Pig's feet, soused	Boiled	1 —	Soup, chicken	Boiled	3 —
Tripe, soused	Boiled	1 —	Oysters, fresh	Roasted	3 15
Trout, salmon, fresh	Boiled	1 30	Pork, recently salted	Broiled	3 15
" " "	Fried	1 30	Pork steak	Broiled	3 15
Apples, sweet, mellow	Raw	1 30	Corn bread	Baked	3 15
Venison, steak	Broiled	1 35	Mutton, fresh	Roasted	3 15
Sago	Boiled	1 45	Carrot, orange	Boiled	3 15
Apples, sour, mellow	Raw	2 —	Sausage, fresh	Broiled	3 20
Cabbage with vinegar	Raw	2 —	Beef, fresh, lean, dry	Roasted	3 30
Codfish, cured, dry	Boiled	2 —	Bread, wheat, fresh	Baked	3 30
Eggs, fresh	Raw	2 —	Butter	Melted	3 30
Liver, beef's, fresh	Broiled	2 —	Cheese, old, strong	Raw	3 30
Milk	Boiled	2 —	Eggs, fresh	Hard boil'd	3 30
Tapioca	Boiled	2 —	" "	Fried	3 30
Milk	Raw	2 15	Flounder, fresh	Fried	3 30
Turkey, wild	Roasted	2 18	Oysters, fresh	Stewed	3 30
" "	Boiled	2 25	Potatoes, Irish	Boiled	3 30
" domesticated	Roasted	2 30	Soup, mutton	Boiled	3 30
Potatoes, Irish	Baked	2 30	" oyster	Boiled	3 30
Parsnips	Boiled	2 30	Turnip, flat	Boiled	3 30
Pig, sucking	Roasted	2 30	Beets	Boiled	3 45
Meat hashed with vegetables	Warmed	2 30	Corn, green, & beans	Boiled	3 45
Lamb, fresh	Broiled	2 30	Beef, fresh, lean	Fried	4 —
Goose	Roasted	2 30	Fowls, domestic	Boiled	4 —
Cake, sponge	Baked	2 30	" "	Roasted	4 —
Cabbage-head	Raw	2 30	Veal, fresh	Broiled	4 —
Beans, pod	Boiled	2 30	Soup, beef, vegetables, and bread	Boiled	4 —
Custard	Baked	2 45	Salmon, salted	Boiled	4 —
Chicken, full-grown	Fricasseed	2 45	Heart, animal	Fried	4 —
Apples, sour, hard	Raw	2 50	Beef, old, hard, salted	Boiled	4 15
Oysters, fresh	Raw	2 55	Pork, recently salted	Fried	4 15
Bass, striped, fresh	Broiled	3 —	Cabbage, with vinegar	Boiled	4 30
Beef, fresh, lean, rare	Roasted	3 —	Ducks, wild	Roasted	4 30
" steak	Broiled	3 —	Pork, recently salted	Boiled	4 30
Corn cake	Baked	3 —	Suet, mutton	Boiled	4 30
Dumpling, apple	Boiled	3 —	Veal, fresh	Fried	4 30
Eggs, fresh	Boiled soft	3 —	Pork, fat and lean	Roasted	5 15
Mutton, fresh	Broiled	3 —	Suet, beef fresh	Boiled	5 30
" "	Boiled	3 —	Tendon	Boiled	5 30

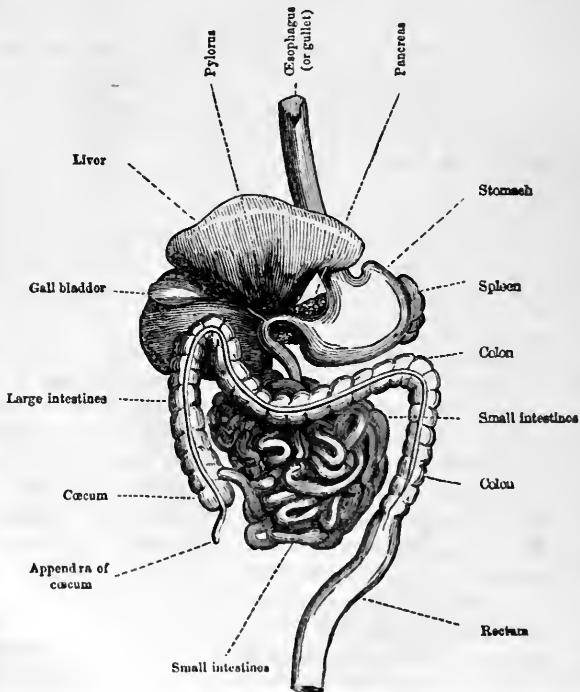
651. **Absorption from the Stomach.**—The power possessed by liquids and gases of penetrating and passing through membranes, is of the highest physiological importance; indeed it is one of the primary conditions of life. The little cell, the starting-point of organization, is a closed bag—without an aperture. All its nourishment must therefore pass through its membranous wall. So also with the perfect animal body. Currents and tides of juices are constantly setting this way and that, through the membranous sides of vessels. The liquefied food is destined to pass into the blood, but there is no open door or passage by which it can get there, and so it enters the circulating vessels by striking at once through their sides. In this way, water drank is absorbed by the minute veins distributed over the surface of the stomach, and enters the circulatory current directly. This

is proved by the fact that when the outlet to the stomach is closed by tying the pyloric extremity, water which has been swallowed rapidly disappears from the organ, and medicines taken produce their effects upon the system almost as promptly as under natural circumstances. In the same way portions of sugar, lactic acid and digested nitrogenous substances, which are dissolved in water, pass into the blood by absorption through the stomach veins. The contents of the stomach thus leave it in two directions,—a portion is absorbed through the coats of the organ, while the unabsorbed matters gradually ooze through the valvular opening that leads into the intestine.

4. Third stage of Digestion—Changes of Food in the Intestines.

652. **Digestive Juices of the Intestinal Tube.**—The partially digested food dismissed from the stomach enters the *duodenum*, the first por-

Fig. 118.



Digestive tract in man.

tion of the intestinal tract (*small intestine*). This is a tube about 20 feet in length, with a surface of some 3,500 square inches, and is the organ designed for finishing the digestive process. The general scheme of the digestive tract in man is exhibited in Fig. 118. Into the duodenum, and but a few inches from the valve of entrance, two small tubes (*ducts*) open, one leading from the liver and pouring in *bile*, and the other from the pancreas, yielding *pancreatic juice*, the quantity of the former being much greater than of the latter. Both of these liquids are strongly alkaline from the presence of soda. The pancreatic juice much resembles saliva in properties; indeed the pancreas itself is so like the salivary glands as to be grouped with them. From the walls of the intestine there is also poured out a fluid called the *intestinal juice*. It is secreted in small but variable quantities, and is alkaline like the other secretions.

653. **Changes in the Intestinal Passage.**—We find that the alkaline digestion of the mouth is now resumed. The starch is attacked energetically and rapidly changed into sugar, and that to lactic acid. The oily substances hitherto untouched by the digestive agents are now acted upon, not perfectly dissolved like the other alimentary matter, but reduced to the condition of an *emulsion*, its particles being very finely divided and rendered capable of absorption. It is believed that the Pancreatic juice is the efficient or principal agent in producing these changes; although the bile undoubtedly contributes to the effect in some way not yet understood. As undigested albuminous matter is constantly liable to escape through the pyloric gateway into the intestines, it seems required that they should be capable, upon emergency, of completing the unfinished work, and such really appears to be the case. Although the secretions poured into the intestine are all distinctly alkaline, yet they convert sugar so actively into lactic acid, that the intestinal mass quickly becomes acidulous,—strongly so, as it advances to the lower portion. The conditions are thus afforded for the digestion of nitrogenous matters in the intestines, which is known often to take place, although their ordinary function is admitted to be digestion of non-nitrogenous substances, starch, sugar, and fat.

654. **Absorption from the Intestine.**—The nutriment being finely dissolved, is absorbed through the coats of the intestine, but not all in the same manner. Those substances which are completely dissolved in water, are taken up by the veins, which are profusely distributed over the intestinal surface, while the oily and fatty matters, which are not so perfectly dissolved, are taken up by a special arrangement of vessels, called the *lacteals*, which are extremely fine tubes arising in the

intestinal coats. They were formerly supposed to be open at their extremities, but they are now seen to present fine, blunt ends to the intestinal cavity. How oily substances get entrance into these tubes is an old physiological puzzle. The membrane is moist, and water repels oil; how then can it be imbibed? Yet it constantly flows through. The thing is accomplished by the agency of cells, which are produced in vast numbers during lacteal absorption. These contain the oil, and bursting, deliver it to the absorbent vessels. The liquid which enters the lacteals is white, milk-like, and rich in oil. These vesecls are gathered into knots (*glands*), so as to be greatly prolonged without consuming space. They finally gather into a tube (*thoracic duct*), and pour their contents into a large vein near the left shoulder. In its route, there is a disappearance of the large proportion of oil; and albumen, which either entered from the intestine, or has afterwards transuded from the bloodvessels into the lacteals, is gradually changed to fibrin, the liquid acquiring the power of clotting or coagulating.

655. **Constipating and Laxative Foods.**—The walls of the alimentary canal having absorbed from its contents such parts as are adapted for nourishment, there remains an undigested residue which passes at intervals from the bowels. The conditions of the intestines in reference to the retention or ready passage of excrementitious matters, is liable to variation from many causes. Amongst these, the nature of the food itself is influential. Some aliments have a relaxing effect, and others are of a binding nature, or tend to constipation, and they differ much in the degree in which these effects are produced. These results are not, however, always due to specific active effects produced upon the bowels; for some foods, as meats, eggs, milk, are considered to be binding, because they are completely absorbed, and leave no residue to excite the intestines to action. Those aliments are best adapted to relieve a costive habit of body which leave much undigested refuse to stimulate the intestines to free action. In this relation we may group the most important aliments, according to their reputed characters, as follows:

THOSE OF A CONSTIPATING TENDENCY.	THOSE OF A LAXATIVE TENDENCY.
Bread and cakes, from fine wheaten flour; rice, beans, peas, meats, eggs, tea, alcoholic drinks.	Wheaten bread and cakes from unbolted flour, rye bread, corn bread, raw sugar, (from the molasses it contains,) fruits, raw and cooked, and generally substances abounding in ligneous matter, as skins, cores, husks, bran, &c.

5. Final Destination of Foods.

656. Digested alimentary matter enters the circulation and becomes BLOOD. This fluid is contained in a system of vessels, which extends to all parts of the body. It has been aptly called the floating capital of the system, lying between absorption and nutrition. Its quantity in an average-sized man is estimated at from 20 to 24 lbs. It is whirled as a rapid stream incessantly through the body, circulating round and round, so as to be brought into relation with all parts (624).

657. **Composition of Blood.**—The composition of blood varies slightly with age, sex, constitution, and state of health; it is also liable to accidental variations, as the supplies to it are periodic and fluctuating, while the draught upon it, though constant, is unsteady. It consists of about 78 per cent. water and 22 per cent. solid food dissolved in it. When evaporated to dryness, the solid matter is found to consist of:

Fibrin Albumen Gelatin	93	per cent.
Fat, a little sugar, and a trace of starch	2	"
Saline matter, or ash	57	"
Blood	100	"

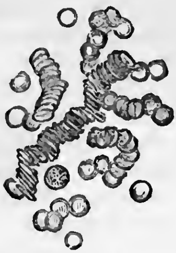
658. **Blood Discs, Globules, or Cells.**—To the naked eye blood appears of a red color, but under the microscope it is seen as a transparent, watery fluid, containing vast numbers of little floating cells or discs, which are the grand instruments of change in the sanguinary fluid. Their minuteness is amazing; fifty thousand would be required to cover the head of a small pin, while in a single drop of blood which would remain suspended upon the point of a fine needle, there must be as many as three millions. And yet each of these little bodies, which dwells down so low in the regions of tenuity that the unassisted eye cannot discover it, seems to be an independent individual, which runs a definite career, is born, grows, performs its offices, and dies like the most perfect being, though the physiologist tells us that twenty millions of them perish at every beat of the pulse. Figs. 119 and 120, from a work of Dr. Hassall, represent different aspects of the blood discs, as seen under the microscope. The physiology of the blood in its details is curious and most interesting, but we have no space to consider it here, and it is not necessary to the general view we propose to give of the final influence of food upon the system.

Fig. 119.

Human red blood globules, showing their natural form and appearance when brought fully into focus.

659. **Grand purpose of the Human Body.**—The living man is presented to our consideration as an engine of power—a being capable of producing effects. The bony framework within is broken into numerous pieces to admit of free motion. A complicated and extensive apparatus of contractile muscles is provided for mechanical movement. The nervous system binds the whole into a co-operating unity, presided over by the brain, which not only regulates and governs the animal nature, but is the material seat of intellectual power. Altogether, the body discloses its supreme purpose to be the reception of impressions by the senses, and the development and expenditure of physical and mental force. But force cannot be produced out of nothing. The body cannot and does not *create* it. As there is no evidence that in the course of events upon the earth, there is either the creation or destruction of a single atom of matter, so it is believed that in no absolute sense is force either created or destroyed. It changes states, disappears, and remains latent or reappears in different forms, but its total amount is thought to correspond with the total quantity and fixed properties of matter. Power is thus not literally *generated* in the body, but is developed or made active there by certain definite causes. It is desirable to understand, as far as we may be able, the conditions of its production.

Fig. 120.



Blood discs, seen united into rolls, like adherent pieces of money.

660. **Food produced by the action of Forces.**—The stream of aliment which flows into the system from without, consists mainly of carbon, oxygen, hydrogen, and nitrogen. These, when left to the undisturbed play of their attractions, take the compound form of water, carbonic acid, and ammonia, natural and permanent conditions of equilibrium from which they are not inclined to depart. These three substances constitute the chief nourishment of the *vegetable* kingdom. Through the roots, or by direct absorption from the air, they get admission into the vegetable leaf, the crucible of nature, where organized compounds originate. They are there decomposed and thrown into new arrangements, forming new compounds. Simple substances, those having few atoms, are destroyed, and the atoms built together into more complex substances, with greater numbers of atoms. The changes are from the lower to the higher, ascending, constructive. Now carbonic acid, water, and ammonia cannot separate and re-arrange *themselves*, nor can they be separated and re-arranged without an enormous expenditure of

power. Man with his utmost skill cannot imitate the first step in the chemistry of the plant. Every green leaf upon the surface of the revolving globe decomposes carbonic acid every day at the ordinary temperatures, *setting free the oxygen*, a thing which the chemist cannot accomplish with all the forces at his command. Nor are we to suppose that the leaf itself does it; that cannot *originate* force any more than the water-wheel or the steam-engine; it must be *acted upon.* Carbonic acid is only decomposed in the leaf during the daytime by the power of light; the effect is produced by solar radiations. All true aliments originate under these circumstances in vegetation. Though we consume flesh, we only go by the route of another animal back to the plant; our food is all fabricated there. Animal life begins and is sustained by compounds which are the last and highest product of the creative energy of plants. The animal is nourished from its blood, but it does not in any sense *produce* it, it only gives it *form;* the constituents of blood are generated in plants, stored up in their seeds, which are the crowning results of vegetable life, and with the maturity of which, most plants employed by man, as food, perish. Aliments are thus composed of atoms that have been forced from a lower into a higher combination in plants, and in their new state they represent the amount of force necessary to place them there. The particles of sugar, starch, oil, gluten, &c., are little reservoirs of power, resembling bent or coiled springs, which have been wound up into organic combination by nothing less than solar enginery. It is these materials, dissolved in water, that constitute blood, and with which the animal system is kept perpetually charged. The circulating medium of the living body is of celestial coinage; it is a dynamic product of astronomic agencies. The energies of the stellar universe itself are brought into requisition to establish the possible conditions of terrestrial life (3).

661. **How Food produces Animal Force.**—Food represents force, but it is force in a state of equilibrium or rest, just like a pond of water enclosed on all sides. But if we make an outlet to the pond, its force at once becomes active and available. So the quiescent force of food is to become active animal power; but how? There enters the vital current incessantly from the outward world another stream of matter, not solid but gaseous, oxygen from the air, which came by the route of the lungs. It is the office of this agent to unlock the organic springs throughout the vital domain. We have stated before that oxygen is an agent of destruction (284); it is the foe of the organized state. The first step of growth, and the production of food in the leaf, con

sisted in forcing carbon and hydrogen out of its grasp; but in the animal fabric it is destined to take possession of them again. The food, as we have seen, is not destroyed in digestion, it is only dissolved; but in the blood and tissues it is destined to undergo a series of decompositions, which are marked by the production of compounds richer and richer in oxygen, until finally they are thrown from the body loaded to their utmost capacity with this substance. The course of changes that characterizes the animal is descending, from higher to lower, from the complex to the simple, from compounds containing comparatively little oxygen to those containing much. In this decomposition of aliment, under the influence of inspired oxygen, bodily force originates. We see every day that steam power results from the destruction of fuel under the boiler by atmospheric oxygen, and that electric power comes from the oxidation or destruction of metal by the liquid in the galvanic battery; but it is equally true that the conditions of human power are the oxidation of food and its products in the system. It is not from the mere introduction of aliment into the system that we obtain strength and nourishment, but from its *destruction*. A portion of food, of course, serves to build up the bodily fabric, but it only continues in that state transiently; it is all finally decomposed and dissevered into the simplest inorganic forms.

662. **Destructive agency of Oxygen.**—The body is built of aliment, which gives rise by its destruction to force, but the immediate active agent which destroys the body, and thus develops force, is oxygen withdrawn from the air. From the moment of birth to the moment of death, every living animal is incessantly occupied in introducing this element into the body to maintain the conditions of force by its constant destructive action. If the current of oxygen flowing toward a limb, a muscle, or the brain, be arrested, those parts instantaneously lose their power of action. The body of every animal is kept charged with this gas every instant of its active existence. If a man is abandoned to the action of air, that is, if no other matter is taken into his system, we quickly discover the peculiar agency of oxygen. He loses weight at every breath. Inspired oxygen, borne by the arterial current, cuts its destructive way through every minutest part, decomposing the constituents of both blood and tissues. The fat is consumed first, then the muscular portions, the body becoming reduced and emaciated, yet the waste must proceed if life is to last. The brain is attacked, its offices disturbed, delirium supervenes, and there is an end of life. We call this *starvation;* it is a condition in which "atmospheric oxygen acts like a sword, which gradually but irresistibly pen-

etrates to the central point of life, and puts an end to its activity." —(LIEBIG.) Had food been regularly introduced, it would have opposed a constant resistance to that agent, that is, it would have offered itself for destruction and for repair, and thus have protected the system from the fatal inroading effects of oxygen.

663. **Combustion within the Body.**—The term *combustion* is commonly applied to that rapid combination of oxygen with other elements, by which a high heat is produced, accompanied with light. But the essence of the process is, not its *rate*, but the nature and direction of the changes. It may go forward at all degrees of speed, the effects being less intense the slower it proceeds. The changes that go on in the body are the same as those in the stove. There is loss of oxygen, destruction of combustible matter, oxidized products (carbonic acid and water), and the development of heat, in one case rapidly, in the other slowly; in both cases, in proportion to the amount of matter changed. The destruction of aliment in the body is, therefore, a real burning; a slow, silent, regulated combustion.

664. **All Foods not equally Combustible.**—Foods are destined to be burned in the body, but they do not all consume alike. We found it necessary, at the outset, to divide the aliments into two great groups, based upon their composition—those which contain nitrogen, and those which do not. We next found a twofold digestion, in which this distinction is recognized; an acid digestion for nitrogenous matters, and an alkaline digestion for the others. And we are now to find that this fundamental difference is observed in their final uses,—in their relations to oxygen, and modes of destruction. All foods are capable of being burned, and *are* burned; but there is a wide difference in their facility of undergoing this change, and upon that difference depends the very existence of the bodily structure. It is clear that if certain substances are to be burned in the blood, and others are to escape from it unburned, the latter must be less combustible than the former, or they would all be consumed together. Accordingly the non-nitrogenous bodies, sugar, starch, oil, are easy of combustion; while the albuminous compounds are burned with much greater difficulty; these latter are drawn out of the blood, and used in the construction of all the tissues of the system. The bodily structures, which require to have a certain degree of permanence, are built of nitrogenous substances, having a low combustibility. The case is roughly represented by what occurs in a common stove. Both the fuel and the stove itself are combustible. The iron is capable of being burned up, under proper circumstances, as truly as the wood or coal; and in

a long time stoves are partially so consumed, or as the phrase is, 'burned out.' Yet the fuel is so much more easily burned, that the iron serves as a structure to retain, enclose, and regulate the combustion. The difference in capability of burning between the non-nitrogenous and the nitrogenous aliments, may not be so great as between iron and wood; yet it is fully sufficient for the purposes of the animal economy.

665. **Nitrogen Lowers the Combustibility of Food.**—Of all the elements of the animal body, nitrogen has the feeblest attraction for oxygen; and what is still more remarkable, it deprives all combustible elements with which it combines, to a greater or less extent, of the power of combining with oxygen, or of undergoing combustion. Every one knows the extreme combustibility of phosphorus, and of hydrogen; but by combining with nitrogen, they produce compounds entirely destitute of combustibility and inflammability under the usual circumstances. Phosphorus takes fire at the heat of the body; while the phosphuret of nitrogen only ignites at a red heat, and in oxygen gas, but does not continue to burn. Ammonia, a compound of nitrogen with hydrogen, contains 75 per cent., by bulk, of the highly combustible hydrogen; but in spite of this large proportion of an element so inflammable, ammonia cannot be set on fire at a red heat. Almost all compounds of nitrogen are, compared with other bodies, difficultly combustible, and are never regarded as fuel, because when they do burn, they develop a low degree of heat, not sufficient to raise the adjacent parts to the kindling point. So with albuminous principles in the blood and tissues; they are placed so low in the scale of combustibility, that the other group of aliments is attacked and destroyed first. "Without the powerful resistance which the nitrogenous constituents of the body, in consequence of their peculiar nature as compounds of nitrogen, oppose, beyond all other parts, to the action of the air, animal life could not subsist. Were the albuminous compounds as destructible or liable to alteration by the inhaled oxygen, as the non-nitrogenous substances, the relatively small quantity of it daily supplied to the blood by the digestive organs, would quickly disappear, and the slightest disturbance of the digestive functions would, of necessity, put an end to life."—(LIEBIG.)

666. **Heat-producing and Tissue-making Foods.**—In considering the final uses of foods, we are to preserve the distinction with which we began. The non-nitrogenous aliments, by their ready attraction for oxygen, seem devoted to simple combustion in the system, with only the evolution of heat; while the albuminous compounds are devoted

to the production of tissue. The first class is hence called the *heat-producing*, *calorifient*, or *respiratory* aliments, while the second is designated as the *tissue-forming*, *plastic*, or *nutritive* aliments (430). This distinction is to be received with due limitation, for on the one hand, fat, which stands at the head of the heat-producers, is deposited and retained in the cells of the tissues, without being immediately consumed, and probably serves other important purposes beside producing heat (722); on the other hand, some nitrogenous substances (as gelatin, for example,) do not reproduce tissue, while those which are worked up into the structure of the system, in their final dissolution, minister also to its warmth. These facts, however, do not disturb the general proposition. That it is the chief purpose of sugar, starch, vegetable acids, and fat, to be destroyed in the body for the generation of warmth; while albumen, fibrin, and casein, furnish the material for tissue, and in their destruction give rise to mechanical force, or animal power,—is a fact of great physiological interest and importance, now regarded as established, and which was first distinctly enunciated, illustrated, and confirmed, by Liebig.

6. Production of Bodily Warmth.

667. **Constant Temperature of the Body.**—The influence of temperature over chemical transformations is all-controlling; they are modified, hastened, checked, or stopped, by variations in the degrees of heat. The living body is characterized by the multiplicity and rapidity of its chemical transmutations. Indeed, the whole circle of life-functions is dependent upon the absolute precision of rate with which these vital changes take place. A standard and unalterable temperature is therefore required for the healthy animal organism, as a fundamental, controlling condition of vital movements—a certain fixed degree of heat to which all the vital operations are adjusted. This standard temperature of health in man, or blood heat, varies but slightly from 98°, the world over. Yet the external temperature is constantly changing, daily with the appearance and disappearance of the sun, and annually with the course of the seasons. We are accustomed to frequent and rapid transitions of temperature, from 30 to 60 degrees, by the alternations of day and night, sudden changes of weather, and by passing from warmed apartments into the cold air of winter. The circle of the seasons may expose us to a variation of more than a hundred degrees, while the extreme limits of temperature to which man is naturally sometimes subjected in equatorial midsummer, and arctic mid-

winter, embrace a stretch of more than 200° of the thermometric scale. Yet through all these thermal vicissitudes, the body of man in health varies but little from the constant normal of 98°.

668. **How the Body loses Heat.**—In view of these facts, it has been maintained that the living body possesses some vital, mysterious, internal defence against the influence of external agents; indeed, that it is actually emancipated from their effects. But this is wholly erroneous; the body possesses no such exemption from outward forces; it is a heated mass, which has the same relation to surrounding objects as any other heated mass; when they are hotter than itself it receives heat, when they are colder it loses heat; and the rate of heating or cooling depends upon the difference between the temperature of the body, and that of the surrounding medium. But in nearly all circumstances, the temperature of the body is higher than the objects around. It is, therefore, almost constantly parting with its heat. This is done in several ways. The food and water which enters the stomach cold, are warmed, and in escaping carry away a portion of the heat. The air introduced into the lungs by respiration is warmed to the temperature of the body, and hence every expired breath conveys away some of the bodily warmth. This loss is variable; as the temperature of the outer air is lower, of course more heat is required to warm it. The body also parts with its heat by radiation, just like any other object, and much is likewise lost by the contact of cold air with the skin, which conducts it away, a loss which is considerable when the air is in motion. This rapid carrying away of heat by air-currents, explains why it is that our *sensations* often indicate a more intense cold than the thermometer. But, lastly, the body loses heat faster by evaporation than in any other way. This takes place from the surface of the skin, and from the lungs. About $3\frac{1}{2}$ lbs. of water are usually estimated to be exhaled in the form of vapor daily, of which one-third escapes from the lungs, and two-thirds from the skin, which is stated to have 28 miles of perspiratory tubing, for water-escape (797). We shall appreciate the extent of this cooling agency, by recalling what was said of the amount of heat swallowed up by vaporization (68). The water of the body at 98° receives 114° of sensible heat, and then 1000° of latent heat, before it is vaporized; hence it carries away 1114° of heat from the body.

669. **How the Body produces Heat.**—To keep the system up to the standard point, notwithstanding this rapid and constant loss, there must be an active and unremitting source within. Heat-force cannot be created out of nothing; it must have a definite and adequate cause.

It is by the destruction of food through respiration, that animal heat is generated. The main physiological difference between the warm and the cold-blooded animals is, that the former breathe actively, while the latter do not. It is natural, therefore, to connect together the distinctive character of breathing, with the equally distinctive character of greater warmth; to suppose that the incessant breathing so necessary to life, is the source of the equally incessant supply of heat from within, so necessary also to the continuance of life; and this connection is placed, beyond all doubt, when we attend to the physical circumstances by which the change of starch and fat into carbonic acid and water is accompanied in the external air. If we burn either of these substances in the air or in pure oxygen gas, they disappear and are entirely transformed into carbonic acid and water. This is what takes place also within the body. But in the air, this change is accompanied by a disengagement of heat and light, or, if it take place very slowly, of heat alone without visible light. Within the body it must be the same. Heat is given off continuously as the starch, sugar and fat of the food, are changed within the body into carbonic acid and water. In this, we find the natural source of animal heat. Without this supply of heat, the body would soon become cold and stiff. The formation of carbonic acid and water, therefore, continually goes on; and when the food ceases to supply the materials, the body of the animal itself is burned away, so to speak, that the heat may still be kept up.—(Johnston.) There are certain periods in the history of the plant, as germination and flowering, when oxygen is absorbed, combines with sugar and starch, and produces carbonic acid and water. In these cases, the temperature of the seed and the flower at once rises, and becomes independent of the surrounding medium.

670. **Effect of breathing rarified Air.**—The doctrine, that animal heat is due to oxidation in the system, is strikingly illustrated by what might be termed *starving* the *respiration.* As cold is felt from want of food, so also it is felt from want of air. In ascending high mountains, the effect upon the system has been graphically expressed as 'a cold to the marrow of the bones,' a difficulty of making muscular exertion is experienced; the strongest man can scarcely take a few steps without resting; the operations of the brain are interfered with; there is a propensity to sleep. The explanation of all this is very clear. In the accustomed volume of air received at each inspiration, there is a less quantity of oxygen in proportion as the altitude gained is higher. Fires can scarce be made to burn on such mountain tops; the air is

too thin and rare to support them; and so these combustions which go on at a measured rate in the interior of the body, are greatly reduced in intensity, and leave a sense of penetrating cold. Such journeys, moreover, illustrate how completely the action of the muscular system, and also of the brain, is dependent on the introduction of air; and under the opposite condition of things, where men descend in diving-bells, though surrounded by the chilly influences of the water, they experience no corresponding sensation of cold, because they are breathing a compressed and condensed atmosphere.—(Dr. DRAPER.)

671. **How the unequal demands for Heat are met.**—The steady maintenance of bodily heat being a matter of prime physiological necessity, we find it distinctly and largely provided for by a class of foods prepared in plants and devoted to this purpose. Much the largest portion of food consumed by herbivorous animals, and generally by man, is burned at once in the blood for the production of heat. But there are varying demands upon the system at different places and seasons, and the provision for these is wise and admirable. First, as the cold increases, the atmosphere becomes more dense, the watery vapor is reduced to its smallest proportion, and pure air occupies its place, so that breathing furnishes to the body a considerably higher percentage of oxygen in winter than in summer, in the colder regions of the north, than in the warmer vicinity of the equator. On the other hand, there is an important difference among the heat-producing principles of food. They vary widely in calorific power. The fats and oils head the list; they consist almost entirely of the two highly combustible elements, carbon and hydrogen, containing from 77 to 80 per cent. of the former, to 11 or 12 of the latter. Starch occurs next in the series, then the sugars, and lastly the vegetable acids and lean meat. LIEBIG states their relative values, or power of keeping the body at the same temperature during equal times, as follows: To produce the same effect as 100 parts of fat, 240 of starch will be required, 249 of cane sugar, 263 of dry grape sugar and milk sugar, and 770 of fresh lean flesh. We shall illustrate this point more clearly, when we come to speak of the nutritive value of foods (743). A pound of fat thus goes as far in heating as $2\frac{2}{5}$ lbs. of starch, or $7\frac{7}{10}$ lbs. of muscular flesh. In regions of severe cold, men instinctively resort to food rich in fatty matters, as the blubber and train oil, which are the staples of polar diet. Bread, which consists of starch and gluten, and which, therefore, as shown by the above illustration, falls far below oleaginous matter in calorifying power, is found to be very insufficient in the arctic regions for the maintenance of animal heat.

All breads are, however, not alike in this respect, for the Hudson's Bay Traders have found, according to Sir JOHN RICHARDSON, that Indian corn bread, which contains about nine per cent. of oil, is decidedly more supporting than wheaten bread. Dr. KANE, in the narrative of his last arctic expedition, remarks: "Our journeys have taught us the wisdom of the Esquimaux appetite, and there are few among us who do not relish a slice of raw blubber, or a chunk of frozen walrus beef. The liver of a walrus, eaten with little slices of his fat, of a verity it is a delicious morsel. The natives of South Greenland prepare themselves for a long journey in the cold by a course of frozen seal. At Upernavick they do the same with the norwhal, which is thought more heat-making than the seal. In Smith's Sound, where the use of raw meats seemed almost inevitable, from the modes of living of the people, walrus holds the first rank. Certainly, its finely condensed tissue, and delicately permeating fat—oh! call it not blubber—is the very best kind a man can swallow; it became our constant companion whenever we could get it." On the contrary, the inhabitants of warmer regions live largely upon fruits, which grow there in abundance, and in which the carbonaceous matter, according to LIEBIG, falls as low as 12 per cent. The demands of appetite seem to correspond closely with the necessities of the system; for while oranges and bread-fruit would be but poor dietetical stuff for an Icelander, the West Indian would hardly accept a dozen tallow candles as a breakfast luxury; but reverse these conditions and both are satisfied. A knowledge of the calorifying powers of the various elements of food, and of the proportions in which they are found, enables us to modify our diet according to the varying temperature of the seasons.

672. **Regulation of Bodily Temperature.**—The question naturally arises, why is it that when the external temperature is 100° and even higher for a considerable time, and the system is constantly generating additional heat, that it does not accumulate, and elevate unduly the bodily temperature? How is it constantly kept down in health to the limit of 98°? This is effected by the powerful influence of evaporation from the lungs and skin, already referred to in speaking of the way the body loses heat (668). The large amount of water daily drank and taken in combination with the food, is used for this purpose as occasion requires. The lungs exhale vapor quite uniformly, but the quantity thrown off from the skin varies with the condition af the atmosphere. When the air is hot and dry, evaporation is active, and the cooling effect consequently greater. During the heat of

summer, much water evaporates from the skin, and a correspondingly small proportion by the kidneys; but in the cold of winter there is less cutaneous exhalation, the water of the body is not vaporized, but chiefly escapes in the liquid form by kidney excretion. As human invention has made the steam-engine beautifully automatic and self-regulating, and as stoves have been devised which adjust their own rate of combustion, and thus equalize the heat, so we find the living body endowed with a matchless power of self-adjustment in regard to its temperature, by the simplest means.

673. **Houses and Clothing replace Food.**—We have seen that the necessity for the active generation of heat within the body is in proportion to the rapidity of its loss. If the conditions favor its escape, more must be produced; if on the other hand the surrounding temperature be high, the loss is diminished, and there is less demand for its evolution in the body. We have also described the various expedients by which heat is produced in our dwellings in winter, thus forming an artificial summer climate. Clothing also acts to protect the body from loss, and enable it to preserve and economize the heat it generates. Hence in winter we infold ourselves in thick non-conducting apparel. Clothing and household shelter thus replace aliment; they are the equivalents for a certain amount of food. The shelterless and thinly clad require large quantities of food during the cold of winter to compensate for the rapid loss of heat. They perish with the same supply that would be quite sufficient for such as are adequately clothed and well-housed. "It is comparatively easy to be temperate in warm climates, or to bear hunger for a long time under the equator; but cold and hunger united very soon produce exhaustion. A starving man is soon frozen to death."

674. **Times of Life when Cold is most fatal.**—The potent influence of temperature upon life must, of course, be most strikingly manifested where there is least capability of resistance—in infancy and old age. During the first months of infant life the external temperature has a very marked influence. It was found in Brussels that the average infant mortality of the three summer months being 80, that of January is nearly 140, and the average of February and March 125. As the constitution attains vigor of development, the influence of seasons upon mortality becomes less apparent, so that at the age of from 25 to 30 years, the difference between the summer and winter mortality is very slight. Yet this difference reappears at a later period in a marked degree. As age advances, the power of producing heat declines, old people draw near the fire and complain that 'their blood is

chill.' The Brussels statistics show that the mortality between 50 and 65 is nearly as great as in early infancy; and it gradually becomes more striking until at the age of 90 and upwards the deaths in January are 158 for every 74 in July. It has been observed in hospitals for the aged, that when the temperature of the rooms they occupy in winter sinks two or three degrees below the usual point, by this small amount of cooling the death of the oldest and weakest, males as well as females, is brought about. They are found lying tranquilly in bed without the slightest symptoms of disease, or the usual recognizable causes of death.

675. **Diet and the daily changes of Temperature.**—The heat of inanimate objects, as stones, trees, &c., rises and falls with the daily variations of temperature. The living body would do the same thing if it did not produce its own heat independently. If we disturb the calorifying process, the body becomes immediately subjected to the mutations of external heat. In starving animals, this temperature rises and falls with the daily rise and nightly fall of the thermometer, and this response of the living system to external fluctuations of heat is more and more prompt and decided as the heat-producing function is more and more depressed. As the system is unequally acted upon by the daily assaults of cold, it becomes necessary to make provision against the periods of severest pressure. In the ever admirable arrangements of Providence, the diurnal time of lowest temperature is made to coincide with the time of darkness, when animals resort to their various shelters to rest and recruit, and are there most perfectly protected from cold. Dr. Draper has suggested also that the diet of civilized man is instinctively regulated with reference to the daily variations of temperature. He says: "In human communities there is some reason beyond mere custom which has led to the mode of distributing the daily meals. A savage may dispatch his glutinous repast and then starve for want of food; but the more delicate constitution of the civilized man demands a perfect adjustment of the supply to the wants of the system, and that not only as respects the *kind*, but also the *time*. It seems to be against our instinct to commence the morning with a heavy meal. We *break fast*, as it is significantly termed, but we do no more; postponing the taking of the chief supply until dinner, at the middle or after part of the day. I think there are many reasons for supposing, when we recall the time that must elapse between the taking of food and the completion of respiratory digestion, that this distribution of meals is not so much a matter of custom, as an instinctive preparation for the systematic rise and fall

of temperature attending on the maxima and minima of daily heat. The light breakfast has a preparatory reference to noonday, the solid dinner to midnight."

7. Production of Bodily Strength.

676. **Amount of mechanical force exerted by the Body.**—We have seen how the double stream of alimentary and gaseous matter which enters the body incessantly gives rise to heat, an agent which we every day convert into mechanical power through the medium of the steam engine. Sufficient heat is produced in this way annually by an adult man, if it were liberated under a boiler, to raise from 25,000 to 30,000 lbs. of water from the freezing to the boiling point. But the body also generates mechanical force directly, producing effects which present themselves to us in a twofold aspect; those which are involuntary, constant, and connected with the maintenance of life, and the voluntary movements which we execute under the direction of the will, for multiplied purposes and in numberless forms. That which produces movement is force, and there can be no movement without an adequate force to impel it. If a load of produce or merchandise is to be transported from one place to another, we all understand that force must be applied to do it. And so with the human body; not a particle of any of its flowing streams can change place, nor a muscle contract to lift the hand or utter a sound, except by the application of force. We may form an idea of the amount generated to maintain the involuntary motions essential to life, by recalling for a moment their number and extent. We make about nine millions of separate motions of breathing, introducing and expelling seven hundred thousand gallons of air in the course of a year. At the same time the heart contracts and dilates forty millions of times—each time with an estimated force of 13 lbs., while the great sanguinary stream that rushes through the system is measured by thousands of tons of fluid driven through the heart, spread through the lungs, and diffused through the minute vessels, beside the subordinate currents and side-eddies which traverse various portions of the body, and contribute essentially to its action. The system not only generates the force indispensable for these effects, but also an additional amount which we expend in a thousand forms of voluntary physical exercise, labor, amusement, &c. A good laborer is assumed to be able to exert sufficient force (expended as in walking) to raise the weight of his body through 10,000 feet in a day. Smeaton states, that working with his arms he can produce an effect equal to

raising 370 lbs. ten feet high, or 3,700 lbs. one foot high in a minute for eight hours in the day.

677. **Tissues destroyed in producing Force.**—The expenditure of force in labor, if not accompanied by a sufficiency of food, rapidly wears down the system,—there is a loss of matter proportioned to the amount of exertion, and which can only be renewed by a corresponding quantity of nourishment. The parts brought into action during exercise are of course those possessing tenacity, firmness, and strength; that is, the tissues and organized structures. The unorganized parts, such as water and fat, which are without texture, have no vital properties, and cannot change their place or relative position by any inherent capability. It is the bodily tissues that are called into action, and these undergo decomposition or metamorphosis in the exact ratio of their active exercise. We have stated that the motions within the system are numerous and constant. If we look on a man externally, he is never wholly at rest; even in sleep there is scarcely an organ which is not in movement or the seat of incessant motion; yet the destruction of parts is correspondingly active. It may vary perhaps in different constitutions, in different parts of the system, and under various circumstances, but it goes on at a rate of which we are hardly conscious. CHOSSAT ascertained the waste in various animals to be an average of 1-24th part of their total weight daily; and SCHMIDT determined it to be, in the case of the human being, 1-23d of the weight. Professor JOHNSTON says: "An animal when fasting will lose from a fourteenth to a twelfth of its whole weight in twenty-four hours. The waste proceeds so rapidly that the whole body is now believed to be renewed in an average period of *not more than thirty days.*

678. **Destination of the Nitrogenous Principles.**—The basis of animal tissue is nitrogen. The muscular masses are identical in composition with the nitrogenous principles of food, albumen, casein, gluten. Those substances have, by digestion, become soluble; that is, they have all assumed the form of albumen, and thus enter the blood. In this liquid, whose prime function is to nourish the system, albumen is always present in considerable quantity. When the fibrin and red-coloring matter (*clot*) is removed from blood, the watery serum or plasma remains, containing albumen, which coagulates like white of egg by heat. Albumen is the universal starting point of animal nutrition; it is the liquid basis of tissue and bodily development throughout the entire animal kingdom. We see this strikingly illustrated by what takes place in the bird's egg during incubation. Under the influence of warmth, and by the action of oxygen, which enters through

the porous shell, under the influence therefore of the same conditions which accompany respiration, all the tissues, membranes and bones, (by the aid of lime from the shell,) are developed. The foundation material from which they are all derived is albumen, and it is the same with the growth and constant reproduction of our own bodies during life. The course of transformation by which albumen is converted into the various bodily tissues, has not yet been certainly traced. But it is now universally agreed that it is the nitrogenous principles of food,—those of low combustibility, which are employed for the nutrition of animal structures—the reparation of tissue-waste. Those substances furnish the instruments of movement, and minister directly to the production of mechanical force. Their design is two-fold, to form and maintain the bodily parts in strength and integrity, and to be finally destroyed for the development of power.

679. **Action of Oxygen upon the Tissues.**—Oxygen plays the same important part in tissue destruction as in the simple development of heat by combustion of respiratory food. It is the agent by which the moving parts are decomposed and disintegrated. The muscles are paralyzed if the supply of arterial blood containing the oxygen which is to change them, and the nutritive matter which is to renew them, be cut off. On the other hand, if there is rapid muscular exercise and consequent waste, the circulation is increased and the breathing quickened, by which the supply of oxygen is augmented. The changes of the tissues in action are, moreover, retrogressive, and downwards to simpler and simpler conditions. The products of metamorphosis are oxidized, and then made soluble in the blood by which they are promptly conveyed away, and thrown out of the body by the liquid excretion. It is thus that oxygen, by slow corrosion and burning of the constituents of the muscles, gives rise to mechanical force. But oxidation is invariably a cause of heat; decomposition of the tissues, therefore, must develop heat at the same time with mechanical effect. Indeed, violent muscular exercise is often resorted to in winter as a source of bodily warmth, by increasing the respirations and muscular waste. In this subordinate way, the nitrogenous aliments become heat-producers. It is not to be supposed that oxygen seizes upon all the atoms of tissue indiscriminately, or upon those which it finds next before it. There is a wonderful selective power, some particles are taken and others left. Those only are seized upon which in some unknown way, perhaps under the regulating influence of the nervous system, are made ready for change.

680. **Relation between Waste and Supply.**—If an organ or part be the

seat of destructive and reparative changes, and its weight remains invariable, we know that an exact balance is struck between these two kinds of transformation. But the processes of destruction and renovation in the body are not necessarily equal, so that every atom that perishes out of the structure is promptly replaced by another. In those cases where the system neither gains nor loses weight, the antagonist forces must of course precisely compensate each other. Yet, even here, the general equilibrium is the result of constant oscillations. The involuntary muscles, which play continually, as those of the heart, and the muscles engaged in respiration, have an intermitting action. The short or momentary period of activity is followed by a corresponding interval of rest. If the first condition involves destruction, the second allows of nutrition. That portion of the mechanism which is independent of voluntary control, is thus self-sustaining. Still, in the case of these parts, the equipoise between waste and supply may be lost, as in bodily growth when nutrition exceeds decomposition, or in deficiency of nutriment, when destruction proceeds at the expense of the tissue, which loses weight faster than the food renews it. As regards the waste and renovation attending voluntary movement, there is the same periodicity. Destruction gains upon nutrition during the exercise of the day, and what was lost is regained by nutrition during rest at night. In sleep, nutrition is at its height while waste falls to its minimum. As bodily exertion costs tissue destruction, which can only be made good again by albuminous substances, it follows that these will be demanded for food, in proportion to the amount of effort expended. If such food be not adequately supplied, or if from any cause the body be incapable of digesting or assimilating it, the apparatus of force begins at once to give way, the acting tissues shrink and fail, for human effort is *carnivorous*, flesh-consuming. If, on the other hand, the system is maintained at rest, that is, if force is not exerted, the nutriment is not used or expended, but is laid up in the body, and serves to increase the mass.

681. **Hastening and retarding tissue changes.**—Ingested substances have a twofold relation to waste or metamorphosis of the tissues. Some, as we have seen, become portions of the animal solids, and then undergo transformation. Others have the power of modifying or controlling these changes, without in the same way participating in them. Some of these *increase* metamorphosis, and others *check* it. Common salt, for example, and an excess of water, act as *hasteners* of tissue change, while alcohol and tea act as *arresters* of metamorphosis. If we consume those substances which augment the waste, it is said we require a fuller diet to compensate for the extra loss, or the body de-

clines in weight with more rapidity than otherwise. If we employ the arresters of metamorphosis, we are supposed to have tissue, and can maintain our usual strength and weight on a more slender diet. That certain substances produce these effects, may be regarded as established, but it cannot be admitted that they are proper aliments. We recognize transformation of the living parts, as the highest and final physiological fact, the necessary condition of human activity. Dr. CHAMBERS remarks—"Metamorphosis is *life*, or an inseparable part of life." Undoubtedly the rates of bodily change are liable to certain variations, within limits of health; but the whole import of the vital economy, leads us to connect accelerated and retarded changes with variations in the exercise of force, by a fixed organic ordinance. With high activity, a rapid change, and with rest, a minimum of loss is evidently nature's purpose, and her law. Substances introduced into the system, which act upon the tissues, as it were from without, and interfere with this fundamental relation between rate of exertion and rate of change, can be regarded in no other light than as disturbers of physiological harmony. Still, we are to be cautious about theoretically prejudging any substance; whether it be beneficial or injurious is ascertainable only by careful observation and experience of its effects.

8. MIND, BODY, AND ALIMENT.

682. **Mind brought into relation with Matter.**—In his ultimate destiny, we contemplate man as an immortal spirit, but in the Divine arrangement, that spirit is to be educated and prepared in nature and time for its onward career. Spirit or mind partakes in nothing of the attributes of matter, but it corresponds closely to our conception of *force*. The passions are regarded as the mind's *motors*, or motive powers. The directive or governing element we call *will*, or will-power. We speak constantly of intellectual force, and mental energy, and regard the mind as an assemblage of faculties or powers capable of producing effects. Indeed, as we consider the Mind or Will of God to be the all-controlling activity of the universe, so the mind of man, created in his Maker's image, is perpetually demonstrating an over-mastering control of the elements and agencies of nature. As mind is thus designed to be developed by action, with the material world for its theatre, it must of course be brought into relation with matter. The brain is the consecrated part where this inscrutable union is effected, and the nervous system is the immediate mechanism which establishes a dynamic connection between the spiritual intelligence and the physical creation.

683. **Mental Exercise destroys Nervous Matter.**—Of the nature of this

union, *how* it is accomplished, we know nothing, but some of its *conditions* are understood. We are certain that the brain and nerves wear and waste by exercise, and require renewal, just like all the other tissues. Nervous matter in this respect is no exception to the general law of the organism. The external universe pours in its impulses through all the avenues of sense, along the nerve routes to the central seat of consciousness, the brain; while the mind, exerting itself through that organ, and another system of nerves, calls the muscles into action, and produces its thousand-fold effects upon external objects. In both cases there is decomposition and loss of nerve-substance, and there must, therefore, be a nutrition of brain and nerves, as truly as of any other part; nay, more truly, for destruction and renovation are perhaps more active in these parts than in any others. Arterial blood, with its agent of disorganization (oxygen), and its materials of repair, are sent to the brain in a far more copious flood than to any other equal portion of the body. Blood-vessels are also distributed most abundantly around the nerves, so as to effect their nutrition in a perfect manner; while if the vital stream be checked or arrested, the nerve loses its power of conducting impressions, and the brain its capacity of being acted upon by the mind; the interruption of the blood-stream through this organ producing instantaneous unconsciousness. Besides, the nerve-tissue consists of the most changeable materials, 70 to 80 per cent. water, 10 of albumen, and 5 to 8 of a peculiar oily or fatty substance, with various salts. It is interesting to remark, that in starvation the parts are disorganized and consumed in the inverse order of their physiological values. First, that which is of lowest service, and can be best spared; the fatty deposits are wasted away, then the muscular and cellular tissues, and lastly the nervous system, which remains undisturbed and intact until the disorganization of other parts is far advanced. The mind's throne is the last part invaded, and the last to be overturned. We are struck with the wisdom of this arrangement, but we cannot explain it.

684. **Can we measure Brain and Nerve waste?**—The appropriation of certain specific parts to certain purposes, is the basal fact of physiology. A part may indeed perform several offices, but they are determinate and limited, and the different portions cannot change duties; the stomach cannot respire, nor the lungs digest, the mind cannot act directly upon the muscular system (only through the intermedium of the nerves), nor can the nerves exert mechanical force. Each part, therefore, does its appropriate work; and as it has a special composition, its metamorphosis gives rise to peculiar products. Muscular de-

composition must hence yield one set of substances, and nerve-waste another. It has been attempted to identify these products, and thus get indications of the amount of change in each part, as a measure of the degree of its exercise. But the results yet obtained are probably only approaches to the truth. Thus, urea is undoubtedly a result of muscular change, and some have regarded its amount in the renal excretion as an index to the degree of muscular exercise. But others affirm that it may also come from unassimilated food, as well as active muscle, which casts a doubt over conclusions thus formed. In the same way, salts of phosphoric acid have been regarded as the peculiar products of brain and nerve waste, and their amount in the kidney evacuations, as a measure of the exercise of brain and nerves. From the researches of Dr. Bense Jones, it appeared that where there is a periodical demand upon the mental powers (as among clergymen, for example, in preparation for their Sunday exercises), there is a corresponding rise in the quantity of alkaline phosphates voided by the renal organs. Yet here, too, there is uncertainty, for we are not sure that these phosphatic salts may not have other sources also.

685. **The Mind's action wears and exhausts the Body.**—That all forms of mental exertion have a wearing, exhausting effect upon the body, producing hunger, and a requirement for food, is well known. Pure intellectual labor, vigorous exercise of the will, active imagination, sustained attention, protracted thought, close reasoning, 'the nobler enthusiasms, the afflatus of the poet, the ambition of the patriot, the abstraction of the scholar,'—the passions and impulses, hope, joy, anger, love, suspended expectance, sorrow, anxiety, and 'corroding cares,' all tend to produce physical exhaustion, either by increasing the destruction of the tissues, or preventing the assimilation of nutriment. It is true that the stunning effect of an emotion, a surge of joy, or a blast of anger, or profound grief, may temporarily overpower the sensation of hunger, that is, prevent its being felt, but after a time the appetite returns with augmented force. In sleep, the mechanism of sense, consciousness, volition, and passion, is at rest, and unhindered nutrition makes up for the losses of the waking hours. If the brain be overworked, either by long and harassing anxiety, or by severe and continued study, it may give way; that is, its nutrition takes place so imperfectly as to produce morbid and unsound tissue, which can only be restored to the healthy state by long mental tranquillity and cessation of effort.

686. **The Phosphatic constituents of Brain.**—We have spoken of the phosphates as special products of brain and nerve waste. That phos-

phorus, in some state, or combination, is a leading ingredient of nervous and cerebral matter, is unquestionable; and that it stands related in some way to the fundamental exercise of those parts, will hardly be doubted. We remember that it is a very remarkable element, shining in the dark (from which it takes its name), and having a most powerful attraction for oxygen, combining with a large amount of it, and generating phosphoric acid with intense heat and light. It is also capable of existing in two states; its ordinary active condition and a passive or inert state, in which it seems paralyzed or asleep, and exhibits no affinity for oxygen. The solar rays have the power of throwing it from the active to the passive form. It has been maintained that in the leaf and by the sun, elementary phosphorus is separated from its compounds, put in the passive state, rocked to sleep (297), is stored up in foods, and thus finds its way into the body, its blood and nervous matter,—and that finally, in the exercise of mental and nervous power, it resumes the active condition, and undergoes oxidation, producing phosphoric acid. In L'Heritier's analysis of nervous matter (quoted by standard physiological authorities), it is stated that the proportion of phosphorus in infants is 0·80 parts per 1,000, in youths' 1·65 (more than double), in adults 1·80, in aged persons 1·00, and in idiots 0·85, thus apparently connecting the quantity of this substance in the brain with maturity and vigor of mental exercise. From this point of view Dr. Moleshott leaps at once to the conclusion, 'no phosphorus, no thought;' Liebig, however, denies point-blanc that elementary phosphorus has ever been found in nervous matter. He says, "no evidence is known to science tending to prove that the food of man contains phosphorus, *as such*, in a form analogous to that in which sulphur occurs in it. No one has ever yet detected phosphorus in any part of the body, of the brain, or of the food, in any other form than that of phosphoric acid." As phosphorus and phosphoric acid, in their properties, are as wide asunder as the poles of the earth, it is highly incorrect to use the terms interchangeably, or (according to the statement of Liebig) to apply the term *phosphorus* in this connection. It may be remarked that the phosphoric compound is a constituent of the oily matters of nerve tissue, which are hence called 'phosphorized fats.'

687. **Are there special Brain Nutriments.**—On the strength of this phosphoric hypothesis, crude suggestions have been volunteered for students and thinkers, to take food abounding in phosphorus, as fish, eggs, milk, oysters, &c. Such advice has no justification in well determined facts. We are not authorized by science to prescribe a diet

specially or peculiarly constructed to promote brain nutrition and protract mental exercise. But while it would seem as if care had been taken to secure these high results in the universal constitution of food, still it is certainly in accordance with analogy, that specific aliments should be adapted, or at all events *best* adapted, to produce certain kinds of effect in the system. Special means for special ends make up the unitary scheme of the living economy. The waste produced by mental exertion is repaired only by food, but to say by *all* food alike transcends the warrant of science. Professor Liebig remarks, "It is certain that three men, one of whom has had a full meal of beef and bread, the second cheese or salt fish, and the third potatoes, *regard a difficulty which presents itself* from entirely different points of view. The effect of the different articles of food on the brain and nervous system is different, according to certain constituents peculiar to each of these forms of food. A bear kept in the anatomical department of this university, exhibited a very gentle character as long as he was fed exclusively on bread. A few days' feeding with flesh rendered him savage, prone to bite, and even dangerous to his keeper. The carnivora are, in general, stronger, bolder, and more pugnacious than the herbivorous animals on which they prey; in like manner those nations which live on vegetable food differ in disposition from those which live chiefly on flesh. The unequal effects of different kinds of food, with regard to the bodily and mental functions of man, and the dependence of these on physiological causes, are indisputable; but as yet the attempt has hardly been made to explain these differences according to the rules of scientific research."

688. **Diet of Brain-workers.**—Yet the diet of the literary, of artists, and those who devote themselves to intellectual labor, is by no means unimportant, and should be carefully conformed to their peculiar circumstances. They should avoid the mistake of supposing that, as they do not work physically, it is no matter how slight their diet, and the perhaps still more frequent error, on the other hand, of excessive eating, the fruitful cause of dyspepsia, and numerous ailments of the sedentary. The best condition of mind corresponds with the most healthy and vigorous state of body. The blood prepared by the digestive and pulmonary organs, and taking as it were its quality and temper from the general state of the system, nourishes the brain and influences the mind. That diet and regimen are therefore best for thinkers, which maintain the body in the most perfect order. They should select nutritious and easily digestible food, avoiding the more refractory aliments, leguminous seeds, heavy bread, rich pastry, &c.

689. **Men seek for Brain Excitants.**—Although specific brain nutrients and thought-sustainers are not determined among foods, yet substances exerting a powerful influence through the brain upon the mind, are but too well known. By a kind of ubiquitous instinct, men have ransacked nature in quest of agents which are capable of influencing their mental and emotive states, and they have found them every where. It is estimated that the peculiar narcotic resin of *Indian hemp* (*haschish*), is chewed and smoked among from two to three hundred millions of men. The *betel nut* is employed in the same way among a hundred millions of people; the use of opium prevails among four hundred millions, and of tobacco among eight hundred million of the world's inhabitants. These substances act powerfully, although somewhat differently, upon the nervous system, and thus directly affect the state of the mind and feelings. We here touch upon the mysterious world problem of *narcotism;* but its discussion, though of absorbing interest, would be too extensive for our limits, besides being foreign to the present inquiry, which is restricted to the general subject of foods. The effects of tea and coffee will be noticed when speaking of drinks (704).

9. Influence of Special Substances.

A.—Saline Matters.

690. **The Ash elements of Food essential to Life.**—When vegetable substances are burned, there remains a small portion of incombustible mineral matter. It was formerly thought that this consisted merely of contaminations from the soil, which happened to be dissolved by water that entered the roots, and was therefore present in the vegetable by accident. We now understand that such is far from being the fact. The ash-principles of food are indispensable to animal life. Indeed, without them neither group of the alimentary substances which we have been considering could do its work. It has been found, in numerous experiments, made upon the lower animals, that neither gluten, casein, albumen, sugar, oil, nor even a mixture of these, when deprived as far as possible of their mineral ingredients, are capable of sustaining life; the animal thus fed actually perishes of starvation.

691. **Acids, Alkalies, Salts.**—We remember that *acids* are bodies having the power of turning blue test paper red, and that *alkalies* change the red to blue. They also combine together, each losing its peculiar properties, and produce *salts.* If the properties of the acid and alkali both disappear, the salt produced is *neutral*, that is, neither acid nor

alkaline. If the acid be stronger, or there be a double or treble dose of it combining with the alkali, the compound is still acid, an *acid salt;* or if the alkali be strongest or in excess, it overpowers the acid and an *alkaline salt* results. If a neutral salt be dissolved in water, the liquid will be neither acid nor alkaline. If an acid salt be dissolved, the water will be acidulous, and produce all the effects of acidity; if an alkaline salt, the liquid will be alkaline, producing alkaline effects. The ash of foods consists of potash, soda, lime, magnesia, oxide of iron, sulphuric, carbonic and phosphoric acids, silica and common salt. Fruits abound in acid salts, that is, powerful organic acids, as oxalic, tartaric, and malic acids, with potash and lime; the acids being in excess. When fruits are burned, the organic acids are consumed or converted into carbonic acid, and the salts become carbonates—neutral carbonates of lime or alkaline carbonates of potash. The quantities of salts, alkalies, and alkaline earths contained in many kitchen vegetables are surprising. Celery (dried), contains from 16 to 20 per cent., common salad 23 to 24 per cent., and cabbage heads 10 per cent.

692. **The Ashes of the Food are Assimilated.**—When the organic matter of food is burned away in the system, a residue of ashes is left, just as in open combustion in the air. But they are not cast at once from the body as useless, foreign, or waste matters. They have important duties to perform as mineral substances, after being set free from organized compounds; and they hence remain dissolved in the blood and various juices of the system. Portions of these mineral matters are constantly withdrawn from the circulation, some at one point and some at others, to contribute to special local nutrition. Thus phosphate of lime is selected to promote the growth of bones, while the muscles withdraw the phosphates of magnesia and potash; the cartilages appropriate soda in preference to potash; silica is selected by the hair, skin, and nails; while iron is attracted to the red coloring matter of the blood, and the black coloring matter within the eye.

693. **The Blood Alkaline, and why?**—But there remains constantly dissolved in the blood and animal juices, a proportion of acids, alkalies, and salts, which impart to these liquids either acid or alkaline properties. The result, however, is not left to accident. Whether a liquid be acid or alkaline is of essential importance in reference to the offices it has to perform. We have seen that it is the determining fact of the digestive juices; one is always acid, and the other alkaline, and their peculiar powers depend upon these properties. So with the blood. It contains potash, soda, lime, mag-

nesia, oxide of iron, phosphoric acid, and common salt; yet these are so proportioned that soda is in excess, and hence the blood of all animals is invariably alkaline. An alkaline condition is indispensable to the action of this fluid. LIEBIG remarks, "The free alkali gives to the blood a number of very remarkable properties. By its means the chief constituents of the blood are kept in their fluid state, the extreme facility with which the blood moves through the minutest vessels, is due to the small degree of permeability of the walls of these vessels for the alkaline fluid. The free alkali acts as a resistance to many causes, which, in the absence of the alkali, would coagulate the albumen. The more alkali the blood contains, the higher is the temperature at which its albumen coagulates; and with a certain amount of alkali, the blood is no longer coagulated by heat at all. On the alkali depends a remarkable property of the blood, that of dissolving the oxides of iron, which are ingredients of its coloring matter, as well as other metallic oxides so as to form perfectly transparent solutions." Alkali in the blood also promotes the oxidation of its constituents. A number of organic compounds acquire by contact with, or in presence of, a free alkali, the power of combining with oxygen (burning), which alone they do not at all possess at the ordinary temperature of the air, or at that of the body.—(CHEVERUL.) The alkalies of the blood exert a precisely similar action, increasing the combustibility of the respiratory foods.

694. **Flesh and its Juices, Acid.**—But while alkali is necessary to maintain the perfect fluidity and combustive relations of the blood, the alkaline state seems unfavorable to *nutrition*. In the ash of muscles, there is an excess of phosphoric acid, and the juice of flesh which surrounds the muscles is also acidulous. The blood nourishes the flesh-juice, and that the muscles, but an acid medium is indispensable to the latter change. Taking the whole body together, acids predominate, so that if the blood were mingled with the other juice, the whole would have an acid character. The chief flesh acids are phosphoric and lactic, but how they influence nutrition is not understood. The remarkable fact of the existence in all parts of the body of an alkaline liquid, the blood, and an acid liquid, the juice of flesh, separated by very thin membranes, and in contact with muscles and nerves, seems to have some relation to the fact now established, of the existence of electric currents in the body.

695. **Uses of Salt in the System.**—The properties of commercial or common salt, have been noticed when speaking of its preservative powers (590). We may now consider its action in the system. It is

a large and constant ingredient of the blood, forming nearly sixty per cent. of its ash. It exists also in other fluids of the body, but is not, perhaps, a constituent of the solid tissues, except the cartilages. Its offices in the system are of the first importance. It increases the solubility of albuminous matters. Dissolved in the liquids of the alimentary canal, it carries with it their important principles, preserves them fluid through the chyle and blood, then parting from them as they become fixed in the tissues, returns to perform the same round again. By decomposition in presence of water, common salt yields an acid and an alkali, hydrochloric acid and soda. This separation is is effected in the system, indeed there is no other source for the hydrochloric acid of stomach digestion. The considerable quantity of soda in the bile and pancreatic juice, which serve for intestinal digestion, as well as the soda of the alkaline blood, are chiefly derived from common salt. A portion comes directly from the food, but by no means sufficient for the wants of the body. Yet it is highly probable, that in the econony of the system, the same materials are used over and over, the acid of the stomach, as it flows into the intestine, combining with the soda it finds there, and reproducing common salt, which is absorbed into the blood, decomposed, and yielded again to the digestive organs. We recollect that common salt consists of chlorine and sodium; it is a *chloride* of *sodium*. Chloride of *potassium* is another salt of apparently quite similar properties. Yet in their physiological effects, they are so different, that while chloride of sodium exists largely in the blood, it is not present in muscles or juice of flesh, chloride of potassium being found there. They seem to have distinct and different offices, and are not replaceable. But the chlorine of the chloride of potassium comes from common salt. It may be remarked, that as phosphate of soda exists in the blood, phosphate of potash belongs to flesh-juice and muscles.

696. **Common Salt contained in Food.**—Salt escapes from the system by the kidneys, intestines, mucus, perspiration, and tears. To replace this constant loss, and maintain the required quantity in the body, there must be a proper supply. It is universally diffused in nature, so that we obtain it both in the solid food we consume and in the water we drink, though not always in quantity sufficient for the demands of the system. Yet the proportion we obtain in food is variable, animal diet containing more than vegetable; though the parts which most abound in this ingredient,—the blood and cartilages—are not commonly used for food. Of vegetable foods, seeds contain the least amount of common salt, roots vary in their quantity,

turnips having hardly a trace. Yet much depends upon its abundance in the soil, and even in the atmosphere; the air near the sea being saline from salt vapor. Plants near the sea are richer in soda than those grown inland, the latter abounding in potash. When we reflect upon the importance of the duties of salt in the organism, and that its necessary proportion in the blood is so much larger than in the food,—often tenfold greater—and besides, that its quantity is extremely variable in our aliments, its almost universal use as a condiment, will not surprise us. The craving for it is very general—probably instinctive—but where it does not exist, we conclude, either that sufficient is furnished naturally in the food and drink, or that animals suffer for the want of it. The quantity annually consumed by each individual in France, has been estimated at 19½ lbs; in England at 22 lbs.

697. **Effects of too little and too much Salt.**—From what has been said, we see that a due supply of salt is of the first necessity; its deficiency in diet can only prove injurious. The most distressing symptoms, ending in death, are stated as the consequence of the protracted use of saltless food. The ancient laws of Holland "ordained men to be kept on bread alone, *unmixed with salt*, as the severest punishment that could be inflicted upon them in their moist climate; the effect was horrible;—these wretched criminals are said to have been devoured by worms engendered in their own stomachs." Taken into the system in large quantity (a table spoonful), it excites vomiting; when thrown into the large intestines, it purges. A too free use of salt engenders thirst; in moderate quantities, it increases the appetite and aids digestion. A long course of diet on provisions exclusively salt-preserved, produces the disease called *scurvy*. This condition of body is believed by some to be due to a deficiency of potash compounds in the system, as in the act of salting, various valuable aliments are abstracted (593). Potatoes, and vegetables rich in potash are excellent *antiscorbutics*—correctives of scurvy. Fresh flesh yields potash to the system unequally; for in that of the ox, there is three times, in that of the fowl, four times, and in that of the pike, five times as much potash as soda. Experiments relating to the influence of common salt upon animals, have given somewhat discordant results. In some cases, it improved their appearance and condition decidedly; while in others, no such result followed. Yet the amount supplied naturally in the food, in the several instances, was not determined. Salt is supposed to be in some way closely allied to the nutritive changes, and some think it increases the metamorphosis of the body; so that a free use of it would only be consistent with a liberal diet.

698. **Carbonates of Soda and Potash.**—The exclusive employment of these substances in extemporising light bread (509), makes a reference to their physiological action necessary. Carbonate of potash in its crude shape, appears as *pearlash;* in its more purified form it is *saleratus.* Crude soda is known as sal-soda or soda-saleratus; refined and cleared of its chief impurities, it forms carbonate and bicarbonate of soda. All these compounds have the common alkaline or burning property, which belongs to free potash and soda; but it is lowered or weakened by the carbonic acid united with them. The potash compounds are the strongest, those of soda being of the same nature but weaker. Yet the system, as we have just seen, recognizes essential differences between them; one pertains to the blood and the other to the flesh. According to the theory of their general use for raising bread, they ought to be neutralized by an acid, muriatic, tartaric, acetic, or lactic, thus losing their peculiar properties and becoming salts. These changes do take place to a certain extent, and the saline compounds formed, are much less powerful and noxious than the unneutralized alkalies; their effects are moderately laxative. Yet, in the common use of these substances, as we have stated, the alkali is not all extinguished; much of it enters the system in its active form. Pure, strong potash, is a powerful corrosive poison; disorganizing the stomach, and dissolving its way through its coats, quicker, perhaps, than any other poisonous agent. When the alkalies are taken in small quantities, as where there is an excess in bread, they disturb healthy digestion in the stomach, by neutralizing its necessary acids (643). They are sometimes found agreeable as palliatives, where there is undue acidity of the stomach; and, on the other hand, they may be of service in the digestion and absorption of fatty substances. It is alleged that their continued use tends to reduce the proportion of the fibrin in the blood. Cases are stated, where families have been poisoned by the excessive employment of saleratus.

B.—Liquid Aliments.

699. **Physiological importance of Water.**—Water is the most abundant compound in the body, constituting 80 per cent. of the blood, and 75 per cent. of the whole system,—in importance to life it ranks next to oxygen of respiration. An adult man takes into his system three-quarters of a ton of it in a year. It supplies some of the first conditions of nutrition, and is, therefore, entitled to head the list of aliments (366). It is the simple and universal beverage furnished by nature, for all living beings, and exists in greater or less proportion, as we have

seen, in all solid food. Vegetables and meats are, at least, three-fourths water; while bread is about 45 per cent. or nearly one half. Athough there is a little water even in the dryest food, yet the demand for it is so great, and its consumption so rapid, that our mixed aliments do not furnish sufficient, while the most nutritious, are the most provocative of thirst. Hence, we daily drink large quantities of it in the free or liquid condition.

700. **Its twofold state in the body.**—Water exists in the body, in the fluctuating, circulating, liquid condition; and also fixed as a solid in the tissues. In the liquid state, it subserves the same great purpose as in the world of commerce, it is an agent of transportation. Its particles glide so freely among each other, as easily to be put in motion, which makes it a perfect medium of circulation, and transportation of atoms. It is the largest constituent of the fleshy parts, serving to give them fulness, softness, and pliancy. Water is a vital and essential portion of the animal structure, but hardly an organized constituent. It is intimately absorbed and held in a peculiar mechanical combination, which permits of separation by pressure. "The milk-white color of cartilage, the transparency of the cornea, the flexibility and elasticity of muscular fibre, and the silky lustre of tendons, all depend on a fixed proportion of water in each case."

701. **Water generated in the Animal System.**—Water in large quantities is as necessary to plants as to animals; but it serves an important purpose in the vegetable world, which it does not, or but to a small degree, in the animal kingdom. Plants decompose it, and use its elements to form their peculiar compounds. The animal possesses this power in but a limited way, if at all; on the contrary, it is one of its leading offices to combine the elements which the plant separated, and thus *produce* water. Hydrogen and oxygen combine continually in the combustion of food, so that in reality, a considerably larger quantity of water is excreted from the system, than was introduced into it in that form.

702. **Influence of Water upon Digestion.**—We have referred to the remarkable solvent powers of water (367). If we could look into the living organism, we should see that its whole scheme is but an illustration of it. Blood, juice of flesh, bile, gastric and pancreatic fluid, saliva, mucus, tears, perspiration, and all other peculiar liquids of the body, are simply water, containing various substances in solution. Indeed, the final result of the whole digestive process is to liquefy the aliments, or dissolve them in water. The effect of taking liquids is of course to dilute the bodily fluids, just in proportion to the amount

taken. The first effect will be a dilution of the gastric juice of the stomach, but the water is rapidly absorbed into the blood, which is thus made thinner. It has been taught that the effect of swallowing much liquid during meals is to lower the digestive power by diluting and weakening the gastric juice. This is, however, denied by high authority. We know that excessive eating is usually accompanied by a copious use of liquids, so that it is easy to commit the mistake of charging the evils of over-eating to the account of over-drinking. In such cases abstinence from drinks may be commended as a means of enforcing moderate eating. Dr. CHAMBERS, of London, asserts that, "A moderate meal is certainly easier digested when diluents are taken with it." Again he remarks, "Aqueous fluids in large quantities during meals, burden the stomach with an extra bulk of matter, and, therefore, often cause pain and discomfort, but that they retard digestion I do not believe. Indeed, among the sufferers from gastric derangements of all kinds, cases frequently occur of those who cannot digest at all without a much more fluid diet than is usual among healthy persons."

703. **Water influences change of Tissue.**—Beyond digestion is metamorphosis of structure, and this is influenced by the amount of water drank. Recent careful experiments by Dr. BOCKER, performed upon himself, show that the use of any quantity of water above the actual demand of thirst, and the essential wants of the system, increase the transformations of the solid parts of the body. He first ascertained what quantity of food and drink was just sufficient to satisfy his appetite and cover the losses of the system. He then found that by continuing the same quantity of food, and increasing the proportion of water, the weight of the body constantly diminished. The excess of water increased the waste, so that the same food would no longer restore it—the balance inclined on the destructive side. Neither the pulse nor respiration were affected, but there was more languor after exercise, while the sensation of hunger kept pace with the increased metamorphosis of matter.

704. **Tea and Coffee.**—These are taken in the form of infusions, the composition and preparation of which have been described (551). They are allied to foods by whatever nutritive constituents they happen to have, which are inconsiderable, and they are distinctly separated from them by possessing certain additional qualities which do not pertain to nutriment. The ingredients to which tea and coffee owe their peculiar action are thein and cafein, tannic acid and volatile or empyreumatic oil.

705. **Effects of Tea.**—Though tea is so universally employed in diet, yet its effects upon the constitution are by no means precisely ascertained. Its tannic acid gives an astringent taste, and a constipating influence in the intestines. It also acts as a diuretic. Thein and volatile oil of tea are its most active ingredients, producing, perhaps jointly, its characteristic effects upon the nervous system. It is acknowledged that tea is a brain excitant, that it influences the mind, and produces exhilaration and wakefulness. How it effects the mental faculties, observers have been unable to decide, judging by their discrepant statements. If the quantity of thein contained in an ounce of good tea (8 or 10 grains), be taken, unpleasant effects come on, the pulse becomes more frequent, the heart beats stronger, and there is trembling of the body. At the same time the imagination is excited, the thoughts wander, visions begin to be seen, and a peculiar state of intoxication supervenes; all these symptoms are followed by, and pass off in, a deep sleep. Dr. Bocker has made several careful sets of experiments upon his own person to determine the physiological effects of tea. He took exact account of the quantity of aliment ingested, of the substances excreted, of his own weight, and the general bodily sensations. His investigations lead to the conclusion, *first*, that tea in ordinary doses has no effect on the amount of carbonic acid expired, the frequency of the respirations, or of the pulse; *second*, when the diet is insufficient, tea limits the loss of weight thereby entailed; *third*, when the diet is sufficient, the body is more likely to gain weight when tea is taken than when not; *fourth*, tea diminishes the loss of substance in the shape of urea, lessens the solid excretions, and limits the loss by perspiration. It is thus claimed that this beverage is an enlivener of the mind, a soother of the body, and a lessener of the waste of the system.

706. **Influence of Coffee in Digestion.**—The active ingredients of coffee are *cafein*, which is identical in properties with thein of tea, and the peculiar empyreumatic or burnt oil produced in roasting. "By the presence of empyreumatic substances, roasted coffee acquires the property of checking those processes of solution and decomposition which are begun and kept up by ferments. We know that all empyreumatic bodies oppose fermentation and putrefaction, and that, for example, smoked flesh is less digestible than that which is merely salted. Persons of weak or sensitive organs will perceive, if they attend to it, that a cup of strong coffee after dinner, instantly checks digestion; it is only when the absorption and removal of it has been effected, that relief is felt. For strong digestions, which are not suf-

ficiently delicate reagents to detect such effects, coffee after eating serves from the same cause to moderate the activity of the stomach, exalted beyond a certain limit by wine and spices. Tea has not the same power of checking digestion; on the contrary, it increases the peristaltic motions of the intestines, and this is sometimes shown in producing nausea, especially when strong tea is taken by a fasting person"—(LIEBIG.)

707. **Lehman on the influence of Coffee.**—We are indebted also to Professor LEHMAN for valuable experiments to ascertain the effects of coffee. He states that coffee produces two leading effects upon the general system, which it seems difficult to associate together, viz: heightening vascular and nervous activity, and at the same time protracting the decomposition of the tissues. The cafein and oil both contribute to the same peculiar stimulant effects, by which it rouses the exhausted system and promotes feelings of comfort and cheerfulness. He finds that in retarding the decompositions of the body, it is the empyreumatic oil of the beverage that chiefly acts, the cafein only producing this result when taken in larger than usual proportion. Excess of this oil causes "perspiration, diuresis, quickened motion of the bowels, and augmented activity of understanding, which may indeed, by an increase of doses end in irregular trains of thought, congestions, restlessness, and incapacity for sleep; and that *excess* of cafein produces increased action of the heart, rigors, derangement of the renal organs, headache, a peculiar inebriation, and delirium."

708. **Chocolate** is allied to tea and coffee by its nitrogenous principle (theobromin), but the effect of this substance seems to be less marked than in the other cases, and has not been clearly traced. It is more nutritive than those drinks from its larger proportion of albumen and fat, but the excess of the latter substance makes it indigestible and offensive to delicate stomachs.

709. **Alcoholic Liquors.**—The common and active principle of spiritous liquors is *alcohol*, obtained from sugar by fermentation. It varies in proportion in the different sorts from 1 to 50 or 60 per cent. Liquors contain various accompanying substances, traces of albumen, sugar, acids, volatile oils, ethers, bitter principles produced in the process of fermentation or distillation, or purposely added to suit the demands of taste. The scale of commercial valuation of alcoholic liquors is made to depend, not on the peculiar spirituous principle, which is cheap, but on the attending flavoring ingredients, and various substances which are said to modify the effect of alcohol upon the system. Yet it is the alcoholic principle found in all these mixtures that

gives them life, and a common character, and groups them all together under the common title of *intoxicating* liquors. It has been insisted by some that alcoholic beverages are entitled to rank as food or nutriment, but the claim is inadmissible, and moreover, is not urged by the most discriminating physiologists, even those who look with favor upon its general use.

710. **They cannot replace Water in the System.**—Water is the appointed solvent within the living body. Aided by acids, alkalies, salts, it brings the various solids into the required condition of solution. But alcohol cannot replace water in this duty. Its solvent powers are not the same as those of water. What alcohol dissolves, water may not, and the reverse. Alcohol mixed with water may deprive it of its solvent powers in particular cases. This is precisely what is done when alcoholic liquids are taken into the stomach. They coagulate, and precipitate the pepsin dissolved in the watery gastric juice, and if not quickly absorbed by the stomach into the blood, they would in this way effectually stop digestion. Their action while within the stomach is to disturb and arrest the digestive process.

711. **They cannot nourish Tissue.**—Alcohol contains no nitrogen; it cannot, therefore, be transformed into tissue, nor take part in metamorphic changes. Its composition forbids the possibility of any such effect, and nobody acquainted with the rudiments of physiology claims it.

712. **Their relation to Animal Heat.**—The assumption that alcohol is a respiratory aliment is plausible at the first blush, but conceding the utmost demand—that it undergoes combustion in the body—it is entirely impossible to sustain the doctrine. True, alcohol gives rise to heat in the system, but so do other agents, whose claim to the character of foods would be on their face preposterous. The question is, do these liquors produce heat in the manner of foods, or in some unnatural and injurious way. By reference to LIEBIG's scale of respirants (743), it will be seen that the strongest spirits drank are inferior, pound for pound, to starch and sugar, and not nearly half so valuable as oily substances for a heat generator. Yet they act in such a rapid, flashy way, as to produce preternatural excitement and irritation in the system. In sustained calorific effect, they are not to be compared with the aliments provided by nature, as is emphatically attested by the concurrent experience of Arctic voyagers exposed to the utmost severities of cold.

713. **Dr. Bocker's Observations.**—This gentleman tested the effects of alcohol in small quantities upon his own person, in a course of skilfully

conducted experiments. He found that this substance diminishes both the solid and liquid constituents of excretion by the kidneys, that it does not increase perspiration, that it diminishes the quantity of carbonic acid exhaled by the lungs, while the quantity of water thrown off by these organs remained unchanged, or, if any thing, was slightly reduced. The general action, therefore, was that of an arrester of the bodily changes. As carbonic acid is hindered from being freely excreted, it accumulates in the blood in poisonous quantities, and thus contributes to the effects of intoxication.

714. **Is its use Physiologically Economical.**—The apologists for the general and moderate use of alcoholic beverages, cannot agree among themselves upon any philosophy to suit the case. Dr. Moleshott says, "Alcohol may be considered a savings-box of the tissues. He who eats little and drinks a moderate quantity of spirits, retains as much in the blood and tissues as a person who eats proportionally more, without drinking any beer, wine, or spirits. Clearly, then, it is hard to rob the laborer, who in the sweat of his brow eats but a slender meal, of a means by which his deficient food is made to last him a longer time." Upon which Dr. Chambers justly remarks, "This is going rather too far. When alcohol limits the consumption of tissue, and so the requirements of the system, while at the same time a man goes on working, it is right to inquire, whence comes his new strength? It is supplied by something which is not decomposition of tissue; by what, then?" Dr. Liebig points out the consequences of that peculiar economy by which the laboring man saves his tissue and the food necessary to repair it by the use of liquors. "Spirits, by their action on the nerves, enable the laborer to make up for deficient power (from insufficient food), *at the expense of his body*, to consume to-day that quantity which ought naturally to have been employed a day later. He draws, so to speak, a bill on his health which must be always renewed, because, for want of means, he cannot take it up; he consumes his capital instead of his interest, and the result is *the inevitable bankruptcy of his body.*"

715. **Stimulating effect of the Beverages.**—They produce general stimulation; the heart's action is increased, the circulation quickened, the secretions augmented, the system glows with unusual warmth, and there is a general heightening of the functions. Organs, usually below par from debility, are brought up to the normal tone, while those which are strong and healthy are raised above it. Thus the stomach, if feeble, for example, from deficient gastric secretion, may be aided to pour out a more copious solvent, which promotes digestion, or if it

be in full health, it may thus be made to digest more than the body requires. The life of the system is exalted above its standard, which takes place, not by conferring additional vitality, but by plying the nervous system with a fiery irritant, which provokes the vital functions to a higher rate of action. This is the secret of the fatal fascination of alcohol, and the source of its evil. The excitement it produces is transcient, and is followed by a corresponding depression and dragging of all the bodily movements. It enables us to live at an accelerated speed to-day, but it is only by plundering to-morrow. By its means we crowd into a short period of intense exhilaration, the feelings, emotions, thoughts, and experiences, which the Author of our nature designed should be distributed more equally through the passing time. We cannot doubt that God has graduated the flow of these life-currents, in accordance with the profoundest harmonies of being, and the highest results of beneficence. By habitually resorting to this potent stimulant, man violates the Providential Order of his constitution, loses the voluntary regulation and control of his conduct, inaugurates the reign of appetite and passion, and reaps the penal consequences in multiform suffering and sorrow,—for nature always vindicates herself at last.*

716. **Effects of Milk.**—This is the food prepared by nature for the complete nourishment of the infant. It is easily digestible, but constipating. There is a difference, however, in different kinds of milk. Cow's milk is richer in butter, or oil, than human milk, or asses' milk, and for this reason often disagrees with delicate stomachs. By *skimming*, however, cow's milk is made to approach human milk in quality. It still, however, contains nearly all the cheese, the sugar of milk, the salts, and some butter. It is therefore scarcely less *nutritious* than new milk, but from its loss of butter is less fattening, and has a lower power of sustaining, through respiration, the temperature of the body. Physicians order milk when they are desirous of affording stimulus or excitement. It is also recommended as a good diet for children, especially in scrofulous complaints.

717. **Properties and effects of Soups.**—The soluble extract of various animal and vegetable substances, obtained by boiling or steeping, forms

* "When, by habit, the stimulant has become a necessity, an enervating relaxation infallibly follows, as sometimes mournfully illustrated by less prudent literary men. The stimulant ceases to excite—the debilitated organs have already been indebted to it for all the activity it can give. In this case the victim continues to seek his refuge, until dangerous diseases of the stomach cripple the digestive powers; with the decay of the digestive organs, the formation of blood and nutrition are disturbed; and with the digestion vanish clearness of thought, acuteness of the senses, and the elasticity of the muscles."—(MOLESHOTT.)

soups. They are made from a great number of materials, and their effects, of course, depend upon the substances they contain. The infusion of meat, which has been described (471), is easily digestible, nourishing, and well adapted to restore the exhausted strength of invalids. The substance which has played the most important part in soups, is *gelatin*, the glue-principle obtained from bones, tendons, cartilages, and membranes. It is this element in soup, procured by long boiling of animal substances, which causes it to coagulate and thicken (*gelatinize*) in cooling, and thus conveys to the uninstructed, the impression of strength and richness. Gelatin is the principle of animal jellies—calves' feet, blanc-mange, &c. It is an exclusive animal product, and never found in plants,—pectin being the vegetable jelly principle. Gelatin is a nitrogenous compound, but not of the protein type. It is regarded as a product of the partial decomposition of albuminous bodies in the system, but is not capable of replacing them when taken as aliment. It is questioned, indeed, if gelatin, taken as such in food, is even capable of nourishing the gelatinous tissues. It is digestible in the stomach along with other nitrogenous matters, and finally contributes slightly, by its destruction to bodily warmth, thus ranking as a respirant of low power. But even this small duty is not performed without detriment, for while the true respirants burn completely away, gelatin loads the blood with its incombustible and noxious residues. The French attempted to feed the inmates of their hospitals on gelatinous extract of bones; murmurs arose, and a commission was appointed, with MAGENDIE at its head, to investigate the matter; the conclusion of which was, that giving the poor gelatin, was just equivalent to giving them nothing at all. The use of gelatin as a nutritive or invigorating substance may be regarded as given up. The utmost claim now put forth for it is, that, mixed with other food, it makes it go further; "but at the same time we must be careful that it is not used in excess, as it is apt not only to weaken the individual by its insufficiency as an article of diet, but causes also diarrhœa, whether by acting as a foreign body, or by some spontaneous decomposition. Hence the unwholesomeness, to healthy stomachs, of dishes containing a great quantity of gelatin, such as mock-turtle soup, calves' foot jelly, &c. At the same time, to invalids they often fulfil very inportant indications. In the first place they dilute nutritious matter, so as to render it capable of being absorbed; then again perhaps they line the irritable membranes with a slimy coat, and it is not impossible that in some cases they are beneficial because *not* nutritious, constituting, in fact, an agreeable mode of abstaining from food."

C.—Solid Aliments.

718. **Starch,** as we have seen, consists of hard, highly organized grains, enclosed in a firm envelope, so that in the raw state they defy the action of the digestive organs. Thorough cooking of starch, to break its grains, is therefore indispensable. We remember that the digestion of starch, altered by culinary heat, begins in the mouth by intermixture with saliva. Its changes in the stomach depend upon such previous intermixture. This explains why it is that those in whom the action of the salivary glands has been impaired (as tobacco smokers, often), complain that starchy food lays like a weight on the stomach. Starch prepared in the form of slops for invalids, as arrow-root, sago, &c., is apt to be swallowed without provoking the salivary flow, which prevents its prompt change; hence starchy matter in the solid form, as bread or potatoes, which require mastication, is likely to be best digested. Starch is mainly changed in the system to sugar, perhaps some of it becomes dextrine and lactic acid.

719. **Sugar.**—Of the behavior of this substance in the system, we know very little positively. A portion of it is absorbed through the veins into the circulation, and then burned away for the production of heat. But it contributes to other objects also. Another part is turned into lactic acid, which may assist stomach digestion, and serve other important uses. Physiologists are now agreed that sugar is capable of conversion into fat in the body. To effect this change, it is only necessary to remove its oxygen, the remaining hydrogen and carbon furnishing the constituents of oil. A deficiency of oxygen in the system is a necessary condition of the accumulation of fat, as an excess of this agent would consume the elements, and thus prevent their deposition. Sugar is of an acid nature, and combines with lime and the alkalies. There is an old opinion, that sugar, when eaten freely, attacks the teeth, corrupting them, and spoiling their color; and recent French experiments are quoted confirming this view. Dr. Pereira declares the opinion totally unfounded, saying that no people on earth have finer teeth than the negroes of Jamaica, who perhaps use sugar most liberally. "It is probable that this erroneous notion has been propagated by frugal housewives, in order to deter children from indulging in an expensive luxury. Their fondness for saccharine substances may be regarded as a natural instinct; since nature, by placing it in milk, evidently intended it to form part of their nourishment during the first period of their existence. Instead, therefore, of repressing this appetite for sugar, it ought rather to be gratified in moderation.

720. **Gum,** in composition, resembles sugar and starch, and, therefore, would seem to be devoted in the system to the same final purpose—the production of heat; but there is no evidence that it is absorbed into the blood, nor indeed satisfactory proof that it accomplishes any alimentary purpose in the system.

721. **Supply of Oily Substances.**—These are furnished to the system mingled by nature with nearly all the food we take. Milk contains three or four per cent. of it, wheat about one per cent., rye 1·75, corn 8 or 9, ordinary meats abound in it, while in butter, gravies, and fat meat, we have it concentrated and almost pure. The roots, as potatoes, beets, &c., contain the smallest proportion of it. The system is thus largely furnished with fat, ready prepared; and moreover, when its supply is deficient, it has the power of producing it out of other alimentary principles, sugar, starch, and perhaps even nitrogenous substances. The physiological services rendered by the fats are manifold and most important. In digestion and absorption, they undergo little or no change. We may consider their uses under a twofold aspect; *first*, when laid up in the body, in a passive state; and, *second*, as participating in the active changes of the system.

722. **The accumulated Fat of the Body.**—The necessity of some substance adapted to fill and occupy the interspaces that must occur between bones, muscles, and vessels, is obvious. There is hence extended across these vacancies a fine tissue of cells filled with fat. But as unimpeded motion is required in all regions of the system, the matter built into these openings and fissures to connect the working parts must be of a nature to facilitate movement. The lubricating, antifriction properties of the oils answer this requirement perfectly; and this effect becomes the more apparent when we consider that the oily matter of the living body is kept by its heat, either entirely fluid, or nearly so. Masses of fat tissue are interposed among the muscular bundles of the heart to promote the ease, freedom and regularity of their movements. The eye, with its retinue of muscles and nerves, is bedded in it; it fills up the interstices of the intestinal cavity, to aid the peristaltic motion of the bowels; layers of it are placed on the soles of the feet and between the bones of the joints, where it serves similar purposes—that of pads and cushions to break the effect of shocks, and the mechanical violence to which the body is constantly liable. Besides, deposited in the layer of cellular tissue, under the skin, it relieves abrupt inequalities of the surface, and rounds the outline into curves of grace and beauty, as we notice most conspicuously in women and children. "The fat which smooths the bony corners

and angles, and the narrow muscles of the face, is the cosmetic employed by nature to stamp the human countenance with the incomparable impress which exalts it far above all the lower animals." Fat in a fluid state is also a *very bad conductor of heat*, so that the layer of it which nature provides under the skin answers an important purpose in protecting the body from the effects of extreme heat and cold, and sudden changes of temperature. Finally, in the course of our experience upon this water-drenched planet, it is often desirable that we should be able to swim, and this is only made possible by the extreme *lightness* of the fatty parts of the body. Were the fat contained in our systems as heavy as water, swimming would be impracticable; besides entailing upon the muscles the increased labor of moving the more weighty limbs and body under ordinary circumstances.

723. **Behavior of Fats in the Stomach.**—We have seen that fats are not digested in the stomach, but are reduced to a fine state of emulsion in the intestines, so as to be capable of absorption. But it has been found that their presence is essential to stomach digestion. LEHMAN ascertained "that a certain, though small quantity of fat, was indispensable to the solution of nitrogenous articles of food during the process of gastric digestion." ELSASSER observed in experiments on artifical digestion, that the solution of articles used as food is considerably accelerated by means of fat. It has been found in the case of dogs with artificial openings in their stomachs, that flesh which had been designedly deprived of fat laid longer in the stomach, and therefore required a longer period for its change than the same substances when mixed or impregnated with a little fat. Yet on the other hand excess of fat exerts an injurious action, especially in persons of weak digestion. Fat in small amount is thus necessary to digestion; in the considerable proportion which the system requires, it ought not to derange the gastric apparatus; but that it is actually a powerful disturber of digestion, in very numerous cases, is well understood. It is probable that those principles which are designed to be dissolved in the stomach, may be so enclosed and pervaded with fat as to cut off the access of the solvent juice, and thus greatly hinder solution. The way in which fat is distributed among the muscular fibres of meat, for example, is one thing that makes it more or less easily soluble by stomachs deficient in gastric juice. "Mutton owes its good character for digestibility to the little fat there is among its close-grained fibres, while the flesh of the ox is infiltrated with oleaginous matter throughout. The oil envelops the fibres when in the stomach, prevents their

being permeated by the gastric secretion, and so renders beef indigestible to all but robust persons. The absence of fat in fish, and in poultry, is one great cause of their easy digestibility in the stomach, though their ultimate fibre is less easily soluble than that of red meat. Meat or fish fried or otherwise dressed with grease is thereby rendered less digestible to weak stomachs, though to those whose gastric juice is sufficiently plentiful to wash away the oily envelope and penetrate the muscular fibre, it is wholesome.—(CHAMBERS.) Even the healthy stomach often recoils at certain combinations of fat, starch and gluten, as in the instance of the oily meats of nuts, filberts, almonds, walnuts, &c.

724. **Cooking influences the Digestibility of Fats.**—The effect of cooking upon fatty substances is generally to render them less agreeable to the stomach, especially if the organ be weak. When speaking of butter, we noticed the complex composition of fats and their liability to be decomposed into various offensive substances. Heat effects these changes rapidly, and to an extent proportional to its intensity. In some, as butter, the bare act of melting produces an unfavorable alteration, which the morbidly delicate stomach detects. In frying, the temperature runs high, tending to decomposition and the production of various acrid and irritant fatty acids. Fatty matters thus changed, or even predisposed to change, are liable to become rancid by the fermenting action of the stomach, producing heartburn and nausea. This explains why cakes are less healthy and digestible than bread. The large proportion of butter, cream, and eggs, (the yolks being rich in oil,) which are usually contained in cakes, and the changes they undergo at the high heat of baking, impairs their digestibility. Dr. PEREIRA remarks: "Fixed oil or fat is more difficult of digestion, and more obnoxious to the stomach, than any other alimentary principle. Indeed, in some more or less obvious or concealed form, I believe it will be found the offending ingredient in nine-tenths of the dishes which disturb weak stomachs. Many dyspeptics, who have most religiously avoided the use of oil or fat in its obvious or ordinary state, (as fat meat, marrow, butter, and oil,) unwittingly employ it in some more concealed form, as yolk of eggs, livers of animals, rich cheese, fried dishes, buttered toasts, suet puddings, &c." Dr. CHAMBERS says: "Fatty food can be taken without pain by gastric invalids, very closely in proportion as it is fresh, and without rancidity. New made butter often agrees, when the empyreumatic fat in baked meat makes it utterly indigestible. If there is much emaciation, it is right to try several forms of oleaginous food in each case, to see if one

cannot be found capable of supplying nutriment to the failing adipose tissue."

725. **Relation of the Fats to Nutrition.**—The fats are ranked as respiratory aliments, but it would be a great mistake to suppose that after absorption from the intestinal passage into the blood they are simply burned away for heat; before their destruction they serve other and capital uses in the body. Fat is an essential constituent of the brain and nervous system; it is thus one of the prime material substances destined to establish communication between mind and matter. It has also been lately maintained that fatty substances have an essential share in the tissue-making process. They do not furnish the material, and we do not know how they act; but it is agreed that their presence is necessary to the formation of cells and the growth of the bodily structure. Thus, in point of fact, oleaginous substances, though at the head of respiratory aliments, are indispensable to nutrition.

726. **Oleaginous Diet and Consumption.**—Masses of crude unorganized matter containing coagulated albumen and half-formed cells, and called *tubercles*, are sometimes found in the lungs, producing *tubercular consumption.* The immediate cause of the disease is an abortive or perverted nutrition, tubercle being produced instead of true tissue. The seeds of consumption are most generally sown in the system in youth, when there is a double demand upon nutrition, for current waste and steady growth. There is, however, sufficient nitrogenous matter present to nourish the structures; some other condition must therefore be wanting. It has been lately maintained that the faulty nutrition which results in tubercle, is caused by a deficiency of oily substances, and therefore such of these bodies as are easiest digested and absorbed have been indicated as remedies. *Cod Liver Oil* has come into use for this purpose. Dr. Hughes Bennett, who first introduced this oil to the notice of the English and American public, states that butchers, cooks, oilmen, tanners, and others who are constantly coming in contact with fatty matter, are less liable than others to tubercular disease; and Dr. Simpson has observed that children and young persons employed in wool factories, where large quanties of oil are daily used, are generally exempt from scrofula and pulmonary consumption. These facts would indicate that even absorption of fatty matter through the skin may powerfully influence nutrition. Dr. Bennett says that, to prevent consumption during youth, indulgence in indigestible articles of food should be avoided, especially pastry, unripe fruit, salted provisions, and acid drinks, while the habit of eating a certain quantity of fat should be encouraged, and, if neces-

sary, rendered imperative. Dr. Carpenter observes: There is a strong tendency, and increasing reason to believe that a deficiency of oleaginous matter, in a state fit for appropriation by the nutritive processes, is a fertile source of diseased action, especially that of a tuberculous character; and that the habitual use of it in larger proportion would operate favorably in the prevention of such maladies, as cod liver oil unquestionably does in their cure. A most remarkable example of this is presented in the population of Ireland, which, notwithstanding the concurrence of every one of the circumstances usually considered favorable to the scrofulous condition, enjoys a most remarkable immunity from it, without any other assignable cause than the peculiarly oleaginous character of the diet usually employed. Dr. Hooker, in a report on the diet of the sick, says: 1st. Of all persons between the ages of 15 and 22 years, more than one-fifth eat no fat meat; 2d. That of persons at the age of 45, all excepting less than one in fifty, habitually use fat meat; 3d. Of those who have abstained, a few acquire an appetite for it and live to a good old age, while the great proportion die of consumption before 45; 4th. Of persons dying of consumption between the ages of 15 and 45, nine-tenths at least have never used fat meat.

727. **Effects of Undue Proportions of Alimentary Principles.**—The digestion and final use of the nitrogenous principles have been explained. When taken in too great quantity, they charge the system with imperfectly assimilated compounds and wrongly-changed products of decomposition, which are not promptly expelled, and which produce a *gouty* state of the constitution, besides influencing the course of other diseases. The excess of oily substances in the food tends to increase the proportion of fat in the body. If more is taken than can be stored up, or consumed by oxidation, and thrown from the skin and lungs, the burden of disposing of it falls upon the liver, the blood becomes charged with the elements of bile, and a *bilious* condition of the system results. The *rheumatic* state of the body, like the gouty, is supposed to be connected with mal-assimilation; but rather with a deficiency of albumen and an excess of lactic acid, derived from a rich, starchy, and saccharine diet. A deficiency of oleaginous substances tends, as we have just seen, to produce the *scrofulous* state, and a lack of fruits and fresh vegetables engenders the *scorbutic* condition of body, or *scurvy*.

728. **Flesh Meats.**—Having considered the action of the constituents of flesh, little needs to be added here concerning their combined effect. The less the fibre of meat has been dried or altered by cook-

ing, the more juicy and abounding in soluble albumen, and the less its fat has been changed from the condition of perfect freshness, either by heat or other causes, the more digestible it is. The flesh of young animals contains less fibrin than that of old ones, but more soluble albumen and gelatin, and is hence more tender. This preponderance of gelatin explains why the broth of veal and lamb coagulates sooner in cooling than that of beef and mutton. Albumen is usually considered the most digestible form of nitrogenous matter. But as the acids of the stomach coagulate it before digestion, it does not appear that liquid albumen is more digestible than that partially coagulated. Eggs boiled, not too hard, are therefore quite as digestible as if taken raw.

729. **Preparations of Flour.**—Of the products of grain and flour which we get in multifarious shapes, baked and boiled, it may be said, their digestibility depends first and mainly upon their condition as respects lightness or heaviness. The porous and spongy state, as in good bread, is most favorable to the penetration and action of the digestive juices, while glutinous masses in a dense compact condition, especially if charged with fat, are the torment of weak stomachs, requiring the strongest digestive powers for their reduction. It is very difficult to preserve the loose and open texture of flour-paste, or dough in boiling, and hence pastry, dumplings, &c., are very rarely light or digestible. Dr. PARIS remarks, "All pastry is an abomination. I verily believe that one-half at least of the cases of indigestion which occur after dinner-parties, may be traced to this cause. The most digestible pudding is that made with bread or biscuit and boiled flour; *batter* puddings are not so easily digested, and *suet* pudding is to be considered the most mischievous to invalids in the whole catalogue." Dr. LEE observes, "It is doubtful whether there is any way of boiling wheat *dough* so as to render it fit for food; it will always be crude, and heavy, and impermeable to the gastric juice. Our best puddings are those made of rice, bread, sago, or Indian meal baked. Boiled Indian puddings are not very indigestible, and are far preferable to those of wheat."

730. **Coarse and Fine Bread.**—As respects the final or nutritive effects of ground grains, it makes every difference whether they be bolted or unbolted. We have stated the composition of flour from the interior of the seed, and the whole flour, which includes the bran (441). The fine or bolted flour has less of the fibre-building gluten, and is therefore less nourishing and strengthening. The unbolted sorts, and even the dark-colored sorts, through which finely-pulverized bran is diffused, are more digestible; the fibrous or ligneous par-

ticles act as a kind of mechanical divisor, separating and diluting the highly-concentrated food, rendering the mass looser and more penetrable to the solvent liquids, and submitting it more gradually to the membranous absorbing surface. The ground grain, or woody fibre, mingled with the flour, together with the adhering oil, are further serviceable by promoting the action of the intestines. Bread from fine flour is constipating, while that from whole flour has an aperient tendency, although it is not purgative. Unquestionably, coarse bread is much superior to fine for maintaining the free and regulated action of the bowels, and Mr. GRAHAM insists strongly, as the result of large observation, that coarse bread is corrective, not only of undue constipating tendencies, but also of morbid and chronic laxity; though at first it may seem to aggravate the symptoms, yet the final result is declared to be most decidedly beneficial. Besides, in the fine flour we miss the full proportion of the elements of bone and tooth nutrition, the essential mineral phosphates. The nourishment of the bony parts must be deficient, having less volume, solidity, and strength, with a diet of fine bread than with the coarser varieties. We have sacrificed several most important qualities, and gained only *whiteness*. We trifle with the first conditions of health to gratify a fancy of the eye.

731. **Beans and Peas.**—The digestibility of these is much dependent upon their preparation. When old and hard, and cooked with their husks and shells, and more especially if boiled in hard water, which prevents the softening and solution of their nitrogenous matter, they are apt to be very indigestible and heating, occasioning flatulence and sometimes colic. When boiled in soft water, the nutritive principle softens, partially dissolves, and becomes more digestible if the husks are separated by passing through a hair sieve. Soup is, therefore, the best form in which dried beans and peas can be taken.

732. **Vegetables.**—The healthful and indispensable influence of fresh vegetables in diet is undoubted. They are rich in valuable saline substances, essential to the system, and probably act by these as *antiscorbutics*,—preventives, and remedies of scurvy. They of course vary in digestibility, according to the proportion of their constituents, and the thorough softening and decomposing effect of culinary heat. Most esculent vegetables abound in indigestible ligneous tissues, which provoke intestinal movement, and thus incline to produce aperient effects. Leaves and young shoots contain organic acids; thus, asparagus and the whole cabbage tribe contain acid of apples, or malic acid; rheubarb, malic and oxalic acid; white cabbage converted into sour krout ferments and yields large quantities of lactic acid. These acids may

contribute to stomach-digestion, promoting the solution of the more nutritive aliments. In the case of fruits, which are still richer in acids, this effect is more marked.

733. **Edible Roots**, of which the potato ranks first, are superior in dietetic importance to the vegetables just referred to. Besides their chief constituents, water, starch, and albumen, potatoes contain malic acid and *asparagin*, a nitrogenous substance existing also in asparagus. Potatoes are rich in all the mineral ingredients required by our bodies, and are of permanent value against scurvy; they especially abound in potash. Turnips contain no soda, but little iron, and considerable potash. Onions have a peculiar volatile oil which is not assimilated or destroyed by the body, but escapes through the lungs, contaminating the breath.

734. **Fruit.**—The delicious and refreshing taste of fruits is caused by a combination of sweets and sours, sugars and acids. The sour taste predominates in the green fruit, for although the quantity of acid increases as the fruit ripens, yet the sugar increases so much faster, that there is a gradual sweetening as the fruit matures. In ripe fruits the acids are enveloped in sugar, just as in stewed fruit they are in the vegetable jelly, produced by stewing. In stewed and prepared fruit, the sugar and jelly cover, or, as it were, mask the acids and salts, and thus check their irritating action upon the interior coating of the digestive passage. The following suggestions of LIEBIG concerning the value of apples, afford us hints of the utility of fruits generally. "The importance of apples as food has not hitherto been sufficiently estimated or understood. Besides contributing a large proportion of sugar, mucilage, and other nutritive compounds in the form of food, they contain such a fine combination of vegetable acids, extractive substances, and aromatic principles, with the nutritive matter, as to act powerfully in the capacity of refrigerants, tonics, and antiseptics, and when freely used, at the season of ripeness, by rural laborers and others, they prevent debility, strengthen digestion, correct the putrefactive tendencies of nitrogenous food, avert scurvy, and probably maintain and strengthen the power of productive labor."

735. **Seasoning Agents, or Condiments.**—Substances taken in small quantities for the purpose of flavoring, and rendering foods palatable, are called *condiments*. Few or none, however, are merely limited to this effect; they serve other purposes besides ministering to the taste. Sugar, oil, acids, and common salt, have been described as aliments, but they are also employed as condiments.

736. **Cheese.**—We may regard cheese as an aliment when consider-

ing it as composed simply of casein and fat, to be digested and absorbed. Thus regarded, it is a highly concentrated food, difficult of digestion. But it is also used in small quantities in a condimentary way, and may thus possess active properties in relation to digestion. Old, changed, and mouldy cheese has long had the reputation of being a *digester*, that is, of assisting in some manner the action of the stomach, and for this purpose it is often taken in trifling quantities after a meal. Being in a state of decomposition, it is capable, when mingled with the contents of the stomach, of exciting fermentation, and thus of assisting the process. Of course, if the cheese be fresh, or not in the mouldy, putrefactive condition, it can be expected to produce no such result.

737. **Vinegar,** in small quantities, by augmenting the acidity of the stomach, may help digestion, assisting the solution of albumen, gluten, and fibrin. It does not, however, dissolve the legumin of peas and beans, but rather precipitates it from solution. An idea has prevailed that the free use of vinegar promotes leanness. However the fact may be, the experiment of reducing corpulence in this way is fraught with the danger of establishing deeply-rooted disease (775).

738. **Spices, &c.**—A class of substances rich in pungent oils,—horse-radish, mustard, pepper, cloves, and various spices, are in extensive request as condiments. These oils produce a heating, irritating effect upon the organs of taste, and the stomach; upon entering the blood, they increase the circulation, and give rise to stimulation. "Condiments, particularly those of the spicy kind, are not essential to the process of digestion, in a healthy state of the system. They afford no nutrition. Though they may assist the action of a debilitated stomach for a time, their continual use never fails to produce a weakness of that organ. They affect it as alcohol or other stimulants do—the *present* relief afforded is at the expense of *future* suffering. Salt and vinegar are exceptions, and are not obnoxious to this charge, when used in moderation."—(Dr. Beaumont.)

10. Nutritive Value of Foods.

739. **Limitation of the Nutritive Powers.**—It is to be expected that substances differing so widely as those which constitute food—substances of such various composition—some containing nitrogen, while others are free from it, some containing sulphur, others none, some an excess of carbon, others the reverse—must serve very different purposes in the economy. Each has its special work to do, while their duties are not interchangeable. A certain degree of variety is thus

the fundamental requirement of the system; and accordingly we find that where nature herself has prepared the food, as in the case of the mother's milk for her young, it is always of a mixed nature, embracing alimentary principles of very different composition. We have no shadow of evidence that the living body possesses the power of converting one element into another; it cannot transmute hydrogen into nitrogen, or carbon into phosphorus; if it lack an element, it must suffer the inconvenience of deficiency. As regards the conversion of one *compound* into another, the system has a limited faculty of this kind in a certain direction; it can effect some changes, as we have seen; it cannot effect others. It can destroy compounds by a progressive series of changes, each descending step being a new substance, but it cannot work upward in a formative direction,—*that* is the office of plants. The materials necessary to form a compound may be present in the body without any power whatever to produce it. The dissevered constituents of used-up tissue, exist in the blood, but it is entirely incapable of reconverting them into tissue. Nor has the body the power of transmuting the respiratory group of aliments into the albuminous, or of enabling the former to replace the latter, in the exigencies of the animal economy. It cannot make starch do the work of gluten. "That none of the non-nitrogenous substances can be made capable, by metamorphosis or combination within the animal body of taking the place of the nitrogenous or plastic compounds, may now be regarded as one of the most certain facts in physiology; the concurrent evidence of experiment and observation tending to the conclusion, that in plants alone can any production of nitrogenous compounds take place. If animals be fed exclusively on saccharine or oleaginous substances of any kind, or in any combination whatever, they speedily perish with symptoms of starvation."—(Dr. CARPENTER.) As the system has no mysterious energy to change *what* it will and *as* it will, its action being absolutely limited, it follows that its nutritive supplies must be adapted to its wants.

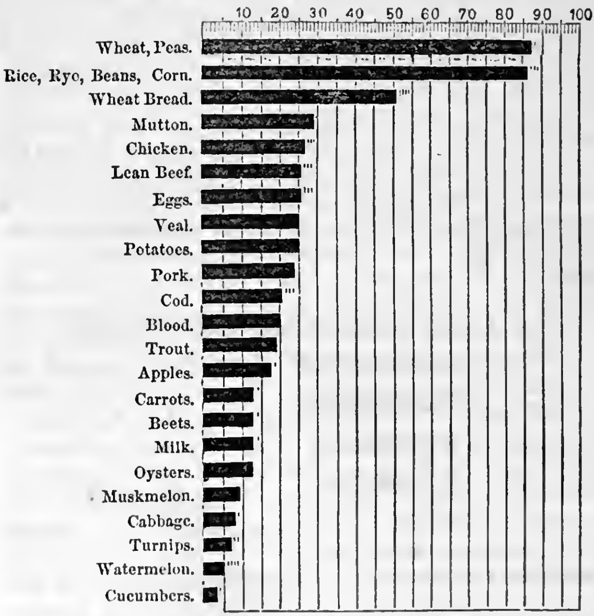
740. **Mixed Diet Indispensable.**—Our diet thus requires to be of a mixed nature, comprehending such a variety of materials as to supply the whole range of bodily wants, and moreover, should be varied with the varying circumstances of growth, bodily and mental exercise, temperature, and numerous changing requirements of the system. Hence the impossibility of prescribing any thing like precise and invariable rules in reference to the quantity and proportions of alimentary substances. We now call attention to the comparative values of nutritive substances, in certain important respects, as based upon composition,

and experience of their effects. We shall have occasion to note both agreement and discordance, in many particulars, between general habits and the indications of science.

741. **Proportions of Solid Matter and Water.**—The following scheme, Fig. 121, illustrates the proportion of solid matter and water contained in the principal articles of diet. They were dried at 212; the results are averages of statements by the best authorities. The length of the bars represent the proportion of dry solid matter in 100 parts, the remainder of the hundred indicated by the scale being water. The preva-

Fig. 121.

PROPORTION OF SOLID MATTER AND WATER IN FOODS.



The length of the bars represents upon the scale, the percentage proportion of solid matter in the various articles of diet, opposite to which they are placed.

lence of the aqueous element in diet, is thus strikingly apparent. Most of the articles contain 75 per cent. water; some much more. The grains are driest, but in being reduced to bread they become more than half water, and even then we take additional liquids freely while eating it. Water is essential to food, but to make the best statement of its nutritive value, we must throw this constituent out of the ac-

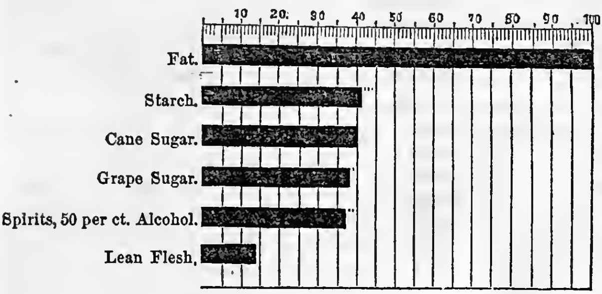
count, and regard only the dry matter. But the quantity of solid substance left, is no guide to its nutritive effect; potatoes and lean beef have the same proportion of water, but they are certainly widely apart in nutritive power.

742. **How far we can measure Nutritive Values.**—A full view of the nutritive value of foods, requires us to take into account all their effects; but we are as yet far from being prepared to do this on any systematic or comparative scale. The nearest approach to a statement that can be ventured, is by classifying foods in reference to the two great leading purposes which they serve in the system—formation of tissue, and production of heat—the proportion of the nutritive to the calorifient principles. This division, although fundamentally true, and capable of being embodied in a valuable shape, we take with its qualifications; for as has been stated, the respiratory principles contribute also to nutrition, while the albuminous may produce heat (666).

743. **Different values of the Respiratory Principles.**—The albuminous substances are identical in composition, and have equal nutritive powers; whether in the form of gluten, fibrin, casein or albumen,

RELATIVE POWERS OF THE HEAT-PRODUCING PRINCIPLES OF FOOD.

FIG. 122.



The relative lengths of the bars illustrate the comparative amount of heat produced in the system by equal weights of the substances mentioned.

they are replacable in nutritive effect. Not so, however, with the calorifient principles; their heat-giving powers are very unequal. The preceding diagram (Fig. 122), exhibits the relative proportions of heat produced by equal weights of the substances mentioned. It will be thus seen that 10 parts of fat go as far as 24 of starch in generating heat. This is LIEBIG's estimate. He calculates the oil as starch, by multiplying it by 2·4. Thus the 9 per cent. of oil in Indian

corn, would be equal to adding 22 per cent. to its real amount of starch. In this way, the nutritive and calorifient powers of foods are readily brought into comparison. It appears from this estimate of LIEBIG, that the strongest spirits are not only incomparably inferior to the oils, in heat-producing power, but also rank decidedly below starch and sugar (712). When we remember that alcohol is derived from sugar by a destructive process, in which half the saccharine substance is lost, and that the product obtained is still below sugar on the heat-making scale; it is clear, that the use of alcohol as a respiratory substance, is any thing but good economy.

744. **Bad Economy of an exclusive Meat Diet.**—It is seen by the foregoing scale, that lean meat is the feeblest of all respirants If it is to be employed, not only for nutrition, but to produce heat, an enormous quantity of it must be consumed. As the largest alimentary demand of the system is for carbon and hydrogen to support respiration, the nitrogenous principles being low in these elements, afford the least economical diet that can be adopted. Thus it has been calculated, that since fifteen lbs. of flesh contain no more carbon than four lbs. of starch, a savage with one carcass and an equal weight of starch, could support life for the same length of time, during which another, restricted to animal food, would require five such carcasses in order to produce the carbon necessary for respiration. The mixture of the nitrogenous and non-nitrogenous compounds, (gluten and starch,) that exist in wheat flour, seems to be just that which is most generally useful to man; and hence we see the explanation of the fact, that from very early ages, bread has been regarded as the 'staff of life.'

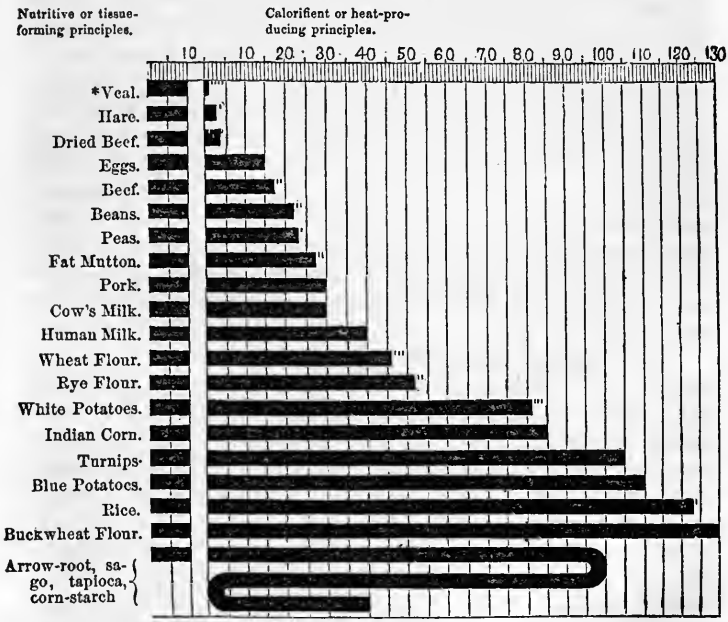
745. **Equilibrium of Values Disturbed.**—When the due proportion demanded by our physiological welfare, is struck, between the nutritive and respiratory principles, they may be regarded as of equal values; that is, they are both, in their just relative amounts, equally necessary, and a diminution of either produces injury. But under ordinary circumstances, the nitrogenous matters are most difficult to obtain. They exhaust the soil most, and the tendency of cropping is to reduce their proportion in equal weights of alimentary products. They represent animal power, are more complex and highly organized, are less easily produced, and more destructible than the other group. The value of foods, therefore, under ordinary circumstances, rises and falls mainly in correspondence with the proportion of these constituents. But in case of famine, or arrest of production, these conditions are reversed. Crops of green roots and vegetables, the immediate and principal sources of respiratory food, in the shape of starch, sugar,

and oil, are cut off. We fall back upon the animal world, but this is chiefly a grand store of nitrogenous matter, without its due proportion of other constituents. The balance being thus lost, respiratory food rises in demand and value.

746. **Proportion of Nutritive to Calorifient Principles.**—The following scheme represents approximately the values, nutritive and calorifient —building materials and fuel—of various articles of food. It must be received as only a general or outline expression of the facts. Different samples of the same food vary in composition; an average is the best result that can be obtained.

FIG. 123.

COMPARATIVE SCALE OF THE NUTRITIVE AND RESPIRATORY VALUES OF VARIOUS ARTICLES OF FOOD.



This scheme represents, by the relative length of the bars, the proportion of nitrogenous to the non-nitrogenous principles in each article given, the latter being all reduced to the value of starch. The upper part of the scale represents those foods which are highest in proper nutritive power, and lowest in heat-producing effect, while the lower portion exhibits those which are lowest in nutritive, but highest in calorifying effect.

* The authorities for the above scale are as follows, in numerical order, counting from the top downward: 1, 2, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 17, 18, 19 (LIEBIG); 3, 4, 16 (Prof. JOHNSTON); 20 (Prof. R. D. THOMPSON); 15 (AUTHOR).

The point to which we called attention in the previous paragraph must not be forgotten, or the scheme will certainly mislead us. The calorifient principles are reduced to the expression for starch, so that wherever fats are involved, the respiratory equivalent appears higher than the quantities furnished by analysis would otherwise warrant. Thus, if we take the weight of the casein of milk to represent its nutritive power, and the combined weights of the sugar and butter to represent the respiratory effect, we shall get a result different from that in the table, 10 of nutritive, to 18 or 20 of respiratory food. LIEBIG says in substance, in connection with this statement, that the relative proportions of the nutritive constituents in milk, to its butter and milk-sugar, that of the plastic matter of flesh to its fat, and of the albuminous substance of grain, potatoes, peas and beans to their starch, are not constant. They vary in milk with the food; fattened flesh contains more fat than that which is lean; and the difference between the two kinds of potato shows how great may be the variation in different varieties of the same plant. But the above may be regarded as average numbers lying between the opposite extremes in each case. We may consider as constant the following results, namely, that peas, beans, and lentils contain for one part by weight of plastic matter, between two and three of non-nitrogenous matter ranked as starch; that grains, such as wheat, rye, and oats, contain between five and six parts, potatoes from eight to eleven parts, and rice and buckwheat from twelve to thirteen parts of the latter, to one of the former.

747. **Nutritive Powers of Milk.**—The above scheme is rich in suggestions. The starting point of all inquiries into the nutritive qualities of foods is milk. It is the only complete or typical aliment fitted to nourish the entire body; the only dietetic prescription that nature has furnished to fill the full circle of bodily wants. The water is there in large proportion to supply the necessary liquids, the mineral salts, to build the bony framework, the casein to form the tissues, and butter and sugar to sustain the bodily warmth. Not only does it contain every thing the system requires, but in proportions exquisitely adapted to the demands of peculiar and varying conditions. It is the appointed diet of the infant, the chief business of which is to *grow*. Its diet must, therefore, not only be adjusted to meet its current waste, but it requires to be especially rich in the structure-making constituents, and such is the fact. The weight of the nitrogenous curd to the butter and sugar, is as high as 1, to 2 or 3. But see how admirably nature modifies these proportions to suit special occasions. Of all the young

of the animal world, none lead so quiescent a life, or advance so slowly to maturity, as does the human infant. The young of other animals more quickly develop, and are called upon to put forth exertion much earlier. Hence the milk of these animals, as for example the cow, is richer in the curdy, or building and strength-giving principle than human milk.

748. **Wheat resembles Milk and Blood.**—Wheat, by universal consent, ranks first in nutritive value among grains. It abounds in the valuable elements which the body requires—mineral matter for bones, gluten for tissue, starch for respiration. Its deficiencies are water and oil; the former we supply in converting it into bread, and the latter by the universal custom of using butter with it when eaten. Another great advantage of wheat is, that its gluten is pre-eminently of that quality which yields the lightest and most digestible bread. The nearness of wheat flour in chemical composition to milk and blood, is shown in the following analytical statement:

Flour.	*Blood.*	*Milk.*
Fibrin,	Fibrin,	
Albumen,	Albumen,	Albumen,
Casein,	Casein,	Casein,
Gluten,	Coloring matter,	
Oil and starch,	Fats and oils,	Butter,
Sugar,	Sugar,	Milk-sugar.
Chloride of potassium,		
Chloride of sodium,		
Phosphate of soda,		
" " lime,	Ditto.	Ditto.
" " magnesia,		
" " iron,		

749. **How Wheaten preparations meet the losses of the System.**—The attempt has been made to determine the daily consumption in the system of nutritive and respiratory matter. The problem is most difficult, and the results thus far only average and approximative. It is assumed that the waste of tissue is about a grain a minute, or 62 grains per hour, or somewhat more than 3 oz. per day. POGGAILE states that the researches of the last 20 years have shown that an adult *laboring man* consumes each day between 11 and 12 ounces of heat-producing principles, and about $4\frac{1}{5}$ ounces (*dry*) of nitrogenous matters, charged with the regeneration of the tissues; that his nourishment is not complete unless it is formed of one part nitrogenous matter and four parts respiratory. BENEKE, from an examination of the diet scales of various educational, invalid, and penal establishments in London, obtains the result that the nitrogenous should be to the non-nitro-

genous as one to five. FRERICHS calculates that the daily consumption should be 2·17 ounces avoirdupois of nitrogenous, and 15·54 ounces of non-nitrogenous food, that is, about as one to seven. Wheat averages, perhaps, one to five. But starch is a bulky form of respiratory aliment, and hence it is only by the use of very considerable quantities of bread, that enough of this ingredient can be procured to sustain the temperature. Butter, a more concentrated heat-producer, comes in to assist in relieving this difficulty, and as wheat is almost entirely destitute of oil, it is highly probable that butter is also instinctively added to promote its digestion.

750. **Variations in Nutritive Value of Wheat.**—The proportion of nutritive to respiratory principles in wheat, fluctuates much, which of course, affects its value correspondingly. Flour containing 9 per cent. of gluten must give rise to very different physiological effects from that containing 18 per cent. The large proportion will produce the blood constituents most copiously, and yield most strength. Yet, as we have repeatedly stated, commercial and nutritive values, so far from coinciding, actually antagonize. Instead of the increasing proportion of nitrogenous compounds being any indication of the price which will be paid for wheat, it is quite the reverse. We prize and estimate flour directly in proportion to its *whiteness*, which is generally in inverse ratio to the proportion of its gluten. We give most for the wheat that will nourish *least*. As the chief object of the farmer is to produce an article which will command the highest *market* price, he has no inducement to cultivate grains rich in albuminous compounds, but a double motive for the contrary course; those which are deficient in these elements exhaust the soil less and bring most money.

751. **High Nutritive Power of coarse Bread.**—In the seventeenth century, VAUBAN estimated the annual consumption of a man at nearly 712 pounds of wheat, a quantity which now nearly suffices for two men; and by the improvements in mills, there are now gained to the population immense masses of nutritious matter, of the annual value of many millions, which were formerly used for animals; the bran may be far more easily replaced by other food not in the least adapted for the use of man. The high value of bran for food has been long ago pointed out. Wheat does not contain above 2 per cent. of indigestible, woody fibre, and a *perfect* mill should not yield more than that proportion of bran, but practically, the best mills always separate, even now, from 12 to 20 per cent. (10 per cent. coarse bran, 7 fine bran, 3 bran flour); and the ordinary mills produce as much as 25 per cent. of bran, containing 60 or 70 per cent. of the most nutritious

constituents of the flour. By baking bread with unbolted flour, the mass of it may be increased from one-sixth to one-fifth, *and the price of it lowered by the difference between the price of the bran as fodder for cattle, and that of the flour gained by not bolting it.* The separation of the bran from the flour by bolting is a matter of luxury, and injurious rather than beneficial as regards the nutritive power of the bread—(LIEBIG).

752. **Aliments may be corrected by Intermixture.**—Lean flesh is the most concentrated form of nutriment, is easily digested, and quickly converted again into muscle. Yet, though a most perfect *nutriment*, it is least fitted to meet the complete demands of the system. It is not a complementary food, like wheat, answering to the double requirements of the body; its deficiency of respiratory matter makes it necessary to consume with it fats and gravies, or else join it with those substances at the opposite extremity of the scale, rice, potatoes, vegetables, &c., which abound in calorifying matter, but are deficient in the nutritive. On the other hand, if we attempt to live exclusively on rice, potatoes, or vegetables, in order to procure sufficient of the flesh-producing ingredients, we must consume an enormous bulk of respiratory matter, so much more than is needed, as to produce deformity and disorder of the system. It is easy to see, however, by reference to the preceding scale, that we can make such combinations of dietetical articles, as shall compensate for natural deficiencies. Indeed, the due admixture of these different principles of food, is a vital and immanent necessity, which, if disregarded, makes itself quickly felt in physiological derangement, so that man's instincts have sufficed to guard him in many cases against broad departures from the proper and healthy course. In all countries we notice dietetical adjustments tending to the same physiological end. In the coarsest and crudest diet of barbarous tribes, or the high-wrought luxuries of the refined, the same instinctive cravings are ever regarded—the same purpose of nature is always in view. Potatoes and vegetables, with beef, mutton, and pork, are almost universal combinations. Beans and peas, which are the most highly concentrated vegetable nutriments, are associated with fat pork, in the well-known dishes—'pork and beans,' 'pork and peas pudding,' and the extreme oiliness of ham or bacon is corrected by the highly nutritive egg (*ham and eggs*). So also milk and eggs are cooked with rice, and butter is added to bread, which is deficient in oily matter. In Ireland, where potatoes form the staple of diet, and there is a deficiency of meat, they attempt a compensation by mingling with the potatoes boiled cabbage, which is rich in nitro-

genous matter, with perhaps a little meat, making a dish known as *kolcannon.* Rice is also a staple article of food through vast regions. It is very deficient as a nutriment, containing but little nitrogenous, fatty or saline matter. It forms an unsubstantial diet, cannot be substituted for meat and dry vegetables in soldiers' rations—and must always be combined with nitrogenous principles. Hence, whenever they can be obtained, milk, fish and meat are added to it; and even with the utmost procurable quantity of these substances, it is questionable whether the natives of rice-eating countries do not owe much of their lack of spirit and power to defective diet.

753. **Diet required by Children.**—We are reminded again, by reference to the preceding scale of equivalents, of the ill-adaptation of rice, sago, arrow-root, corn-starch, &c., as diet for children. Milk, rich in nutrient matters, is their typical food. They require nitrogenous substances, for the double purpose of present waste and growth. When fed on the substances just mentioned, which lack both nitrogenous and mineral substances, fat may indeed accumulate, but the frame is weak and rickety, from small muscles and softness of bones. Children should have a full supply of blood-producing food—even bread contains too little for them—milk or flesh should be added. But whether fed on bread and milk, or meat and bread, there is apt to occur a deficiency of phosphate of lime, from the rapid formation of bone. But as meat, eggs and milk contain an excess of phosphoric acid, there being not enough lime to convert it all into phosphate, lime itself is a good addition to the food of young children. It may be given in the form of lime-water, which the peasants of Germany give to their children with the best results, while the children greedily take it, guided by instinct. —(GREGORY.)

11. THE VEGETARIAN QUESTION.

754. **The points in Controversy.**—Strenuous objection to the use of animal diet has been made by many, and pure vegetable products commended as the best food of man. The controversy has been between the advocates of a mixed diet, of vegetable and animal substances, on the one hand, and the partisans of an exclusive vegetable diet, on the other; the point of contention being the dietetical fitness of animal food. The vegetarians, however, as a school, do not entirely proscribe animal diet. They generally admit the use of eggs, milk, butter, and cheese, but repudiate flesh. Mr. GRAHAM recognizes the inconsistency of this course with the true vegetarian theory, and regards the use of those substances with disfavor, tolerating them, as it might be, under

protest. The quarrel is an old and embittered one, and has been made to involve all sorts of considerations. We epitomize and contrast below, some of the arguments and objections which are most commonly started in the course of this discussion.

ADVOCATES OF VEGETABLE DIET.	ADVOCATES OF MIXED DIET.
Flesh diet involves the barbarous and unfeeling practice of destroying sentient life.	So does the necessary clearance of household pests, and the insects and vermin injurious to the farm and garden. It is involved in the fundamental order of nature.
In a state of primitive nature, man lived on vegetable products, fruits, and grains of the earth.	If so, it was because he knew no better; he is a progressive being, designed to be civilized, and improve his condition in numberless ways.
Whatever may be true concerning the natural dietetic character of man, there is neither now on earth, nor has there been for many centuries, any portion of the human race, which has lived in all respects so perfectly in a state of nature, as to afford us an opportunity to study man's true natural history and dietetic habits. Anatomically, and in strict propriety, man must be regarded as an *extinct species*, that is, he has become so artificial in his dietetic habits, that they afford no evidence of his natural dietetic character. Man's alimentary organs, if placed before us, afford no clear and determinate indications of his true dietetic character—his natural habits in this respect are wholly unknown, except as matter of history and tradition.—(SYLVESTER GRAHAM.)	The anatomical structure of man proves his adaptation to a mixed diet. The herbivorous animals are enabled by numerous and variously-formed teeth to gnaw and grind, and by a longer digestive canal, and larger salivary glands, to digest substances which could not be sufficiently reduced by the differently structured and sharper teeth of carnivorous animals, nor dissolved by their smaller salivary glands, and shorter intestinal canal. In the structure of man's stomach and intestines, teeth and jawbones, salivary glands, and muscles of mastication, we find a medium between these extremes, which points to a compromise in his diet, and indicates that he was designed to use both forms of food.
Vegetables afford the pure, first principles of nature; while animal products are drossy, corrupted, second-hand residues, from which the finer and subtler essences have been, as it were, exhaled and lost.	There is no proof of any such difference; the foundation of our being is laid in animal nutrition; the infant in the early stages of its life, is exclusively nourished by its mother's blood and milk. It is ordered, at all events, that we shall not *begin* our career as vegetarians,—a pretty distinct providential hint!
The meat of diseased animals being eaten, is liable to introduce the same diseases, or others, into the human system.	Diseased meat is of course unwholesome, dangerous, and to be rejected; but so are diseased grains, and damaged flour; both are liable to engender disease.
Animal diet excites and inflames the animal passions and propensities, favoring cru-	But does not the carnivorous animal eat flesh *because* it is ferocious, that is, because

elty and ferocity of disposition, as seen in the carnivora; while vegetable food produces mildness and docility of disposition (687).

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the Creator has implanted in it the instincts necessary to its *acquirement* of the food for which its organization is destined; and that the herb and grain eaters are without this savage nature, because they have no occasion for it, being intended to derive their food from the produce of the soil. But if we admit that the habitual diet reacts upon, and tends to keep up the respective propensities of these two classes, still there is nothing in vegetable food that necessarily induces mildness and docility. The ferocity of wild bulls, boars, buffalos, &c., is well known. Our domesticated animals are not in their natural state, an active source of excitement and danger being removed, in the general mutilation of the males. "We cannot see the least ground for the conviction, that a man, in good average health, with no plethoric excitability, will be in the least changed for the better by relinquishing his slice of mutton and potatoes for its equivalent in wheat-flour, or an omelet and custard-pudding. And if the effect of universal vegetarianism were to be, to reduce the character of all mankind to the insipidity of said omelet, and the blandness of custard-pudding, we, for our part, should not like the world half so well as we do now. A very excellent lady, who had kept a school for nearly half a century, said—'I never liked the girls who were brought to me with "very good characters" from their parents; they had either no energy, or were very sly; give me the naughty children; there is something in them to work upon, and a promise of future activity.' The emotions and propensities are the sources of all *action*, and if these be tamed down to the vegetarian standard, we apprehend that, neither will the better parts of human nature be called into energetic operation by their own activity; nor will the worse call forth that energy for their repression, which is often the foundation of what is noblest in human character."—(Dr. Carpenter.)

Into the general question, as thus opened, we do not propose to enter; but simply to call attention to a few chemical and physiological facts, which appear to have been established, and which may enable us, perhaps, better to comprehend the present conditions, and more strictly scientific aspects of the subject.

755. **Restricted Scope of Animal Transformations.**—We recall at this point the statement repeatedly made, that the animal system is not to be viewed as capable of creating or fabricating the compound substances which it employs in nutrition. Recent organic chemistry has profoundly modified the older views of this matter. In the absence of all accurate information, the animal system was looked upon as endowed with unlimited and mysterious powers of transformation; but we now understand that those powers are definite, and limited within a narrow range. It is not strange that, in the absence of exact knowledge, but little could be discovered in common between herbage and dried leaves of grass consumed by an ox, and the blood and texture of its body. But chemistry teaches us now that the very identical material of blood and tissue is prepared in the vegetable, and that the office of the animal is chiefly limited to extracting and collecting it from its multifarious vegetable food; it can only appropriate pre-existing compounds.

756. **Vegetable and Animal Principles the same.**—We have further seen that there is a remarkable identity of alimentary principles, whether derived from plants or animals. Vegetable and animal fats have the same substantial composition—are alike divisible into liquid and solid parts, with similar properties. And so the nitrogenous principles, vegetable and animal, are remarkable for their chemical similarity—in composition, the proportion of their elements, external properties, and modes and products of decomposition, vegetable albumen resembles animal albumen, and the same with casein and fibrin. The vegetable principles, by simple digestive solution, are converted into blood and flesh, without decomposition, just as mineral substances may be dissolved and separated, again and again, without affecting their chemical integrity or essential properties. Whether we go to the vegetable or animal world, therefore, we get the same nutritive principles, and we arrive at this twofold conclusion: that, while we may procure every thing adequate to complete and healthful sustenance from the vegetable kingdom, where it is all first fabricated; on the other hand, we find substantially the same principles in the animal world, with only modifications of form, concentration, and solubility. It would seem from this point of view, that we may confine ourselves without detriment to the former source of aliment, or resort without injury to the latter.

757. **Peculiar Influence of Flesh Diet.**—Yet there are important differences between vegetable and animal food; in what do they consist? LIEBIG observes, "Bread and flesh, or vegetable and animal food act in the same way with reference to those functions, which are common to man and animals; they form in the living body the same products. Bread contains in its composition, in the form of vegetable albumen and vegetable fibrin, two of the chief constituents of flesh, and in its incombustible constituents, the salts, which are indispensable for blood-making, of the same quality and in the same proportion as flesh. But flesh contains, besides these, a number of substances which are entirely wanting in vegetable food; and on these peculiar constituents of flesh depend certain effects by which it is essentially distinguished." Reference is here made to the peculiar constituents of flesh-juice which have been mentioned (471). Flesh is thus a complex product, containing peculiar principles,—a result of all the digestive and preparative actions of an animal organism; and as the purpose of food is to re-produce flesh, it is evident that no dietetical preparation can effect this so perfectly, so rapidly, or with so little physiological labor as meat itself. Flesh is nearest to blood, and flesh

of all aliments is most easily converted into both. The ingestion of flesh augments the proportion of fibrin in the blood, and increases the activity of nutrition. The heart being a tissue of muscular fibres, is more fully nourished; the activity of the circulation is consequently increased. The excitation of this activity, observed after a copious meal of venison, is due not only to the abundance of albuminous matters contained in the venison, but also, probably, to its proportionately large quantity of kreatin. Highly animalized diet exalts the density and solid constituents of the blood, and increases the number of its corpuscles or globules; but does not augment the proportion of its albumen. This re-enforcement of the blood by consumption of flesh, in heightening the general power of the system, of course, strengthens the passions and propensities. For this reason the term *stimulating* has been applied to flesh-diet. From its greater concentration, it is easier to over-eat with animal than with vegetable diet. As excessive alimentation is a universal danger, the vegetarian is most protected, though by no means safe; for it is very easy to slide into excess upon a vegetable regimen, especially if eggs, milk, butter, and cheese be freely used, as is very apt to be the case.*

758. **Mineral Matters Replaceable in the two Diets.**—But while vegetable and animal food yield precisely the same organic principles to the blood, they do not furnish to it identical mineral constituents, as was stated before. The phosphoric acid which appears in the blood in combination with the alkalies forming *phosphates*, when animal food is consumed, is replaced by carbonic acid, and the *carbonates* when we change to a diet of vegetables, and fruits. Bread gives rise to phosphoric acid like flesh. We called attention to this most extraordinary fact—that a powerful, fixed, mineral acid, and a feeble, volatile, or-

* "The influence of diet over muscular fibre, is an important social question; for thews and sinews have always ruled the world, in peace and in war, in a proportion quite equal to brains. Indeed, it is a question which the present writer is disposed to answer in the affirmative, whether *nationally* muscular and mental energy do not always run in couples and whether the first is not the cause of the second. It does not appear that any diet, so there be plenty of it, is incapable of fitting a man to get through his daily work *in a fashion;* but the best specimens of the species in their several sorts, hunters, agriculturists, or citizens, are those nations who get most flesh-meat. A collateral advantage of a meat diet to a nation is the difficulty of obtaining it; for the truth, probably, is that the mode of procuring food has as great an influence over mind, manners, and muscles, as the nature of the food itself. He that is satisfied with what he can pick up, ready grown, degenerates either into a starved New Hollander, where food is deficient, or into an effeminate creature like the old inhabitants of the West Indies, where it is abundant; while a civilized people with 'a care for their meat and diet,' will have thought about it, labored for it steadily, advanced science, and ransacked nature, to improve it, and obtained their reward in the search itself.' "—(Dr. CHAMBERS).

ganic acid, deport themselves alike, and produce exactly the same effects, in that most delicate and changeable of all chemical preparations—the blood of the living body. We can hardly suppose that these widely dissimilar substances would have been made so perfectly interchangeable under these circumstances, except to provide for the possibility of a mixed and variable diet.

759. **Indications from the Saliva.**—Attention has been called to the saliva, as affording a possible test of the kind of food adapted to different animals. Human saliva is much more powerful in its action than that of carnivorous animals, as the dog. This evidently points to a diet abounding in starch as proper for man, while the contrary is clearly indicated in reference to the dog.

760. **Relative Economy of Vegetable and Animal Diet.**—If the question present itself as one of economy on the largest scale, that is, under which diet the greatest number of human beings can be sustained on a given area, we must decide at once in favor of the vegetarian policy. All animals are organisms for the destruction of nutritive matter. When an animal is slaughtered, it affords a mass of nutritive material; but it is only a residue,—a small remaining part after life-long waste and destruction of food. The body of the ox represents, perhaps, thousands of bushels of grains and roots which it has consumed. If we obtained from him force, in the shape of work done, the loss was not total; otherwise, a few hundred weights of beef is our sole equivalent for the destruction of many tons of vegetable food. The amount of nutritive material procurable upon a given surface of the earth, is definite and limited, and the inferior animals are machines for its destruction; in consuming them, we take what happens to remain, and besides the previous necessary loss, the nutriment we get comes in the worst possible shape in point of economy (744). If grains, leguminous seeds, fruits, and roots, are cultivated—nutriments adapted to the sustenance of men; and the lower animals be dispensed with, the conditions are provided for the largest human population. The great superiority of agricultural communities in numbers and power, over the hunting and flesh-consuming races, is thus obvious. The case was pithily put by a North American Chief, who, according to the French traveller CREVICOUR, addressed his tribe as follows: "Do you not see the whites living upon seeds, while we eat flesh? That the flesh requires more than thirty moons to grow up, and is then often scarce? That each of the wonderful seeds they sow in the earth, returns them a hundred fold? That the flesh on which we subsist has four legs to escape from us, while we can use but two to pursue and

capture it? That the grains remain where the whites sow them, and grow? That winter, which with us is the time for laborious hunting, to them is a period of rest? For these reasons have they so many children and live longer than we do. I say, therefore, unto every one that will hear me, that before the cedars of our village shall have died down with age, and the maple trees of the valley shall have ceased to give us sugar, the race of the little corn-sowers, will have exterminated the race of flesh-eaters, provided their huntsmen do not themselves become sowers."

761. **Diversities of Diet among different Nations.**—The adaptability of the human constitution to widely different dietetic conditions, is remarkable. We find among the races distributed over the globe, the pure vegetarians,—some subsisting upon soft fruits, others upon hard grains, others upon succulent herbage, and others again upon tough fibrous roots. On the other hand, there are the exclusive animal feeders, some consuming flesh, others fish, others fowl, and others even insects;—some devour their food raw, others cook it; some take it as soon as it has ceased to live, and others wait till it turns putrescent. Thus the diet of one locality would become loathsome and fatal in another. It has been affirmed that this dietetic pliancy of man, by which he is enabled to live upon the most strangely diverse forms of aliment, is a wise providential design to secure the diffusion of the human race, and the most extended occupancy of the earth. But though this be admitted, it brings us no nearer to a settlement of the question, "What form of diet is best suited to the full and harmonious and highest development of man's nature?" that is one of the large and serious problems to which science will address itself in the future.

12. Considerations of Diet.

762. We conclude the subject of the physiological action of foods with some general and practical suggestions concerning diet, partly in recapitulation and partly supplemental.

763. **The demand for Food variable.**—By recalling the purposes to which food is applied, we perceive how changeable must be the demand for it. It is the source of power, and therefore, with the alternations of exercise and rest, its requirement rises and falls. It is the source of warmth, and therefore the quantity we need must vary with our protection from cold. Any cooling of the body increases the appetite, and compels us to eat more than usual. Again, the necessity for food is complicated with the conditions of breathing. The waste

of matter in the body stands in close relation to the oxygen it consumes, and this varies with capacity of the lungs, atmospheric purity and density, and therefore influences the quantity of food necessary to restore the bodily loss. A Manchester manufacturer ventilated his weaving mill, when forthwith the appetites of the operatives were sharpened, and as their wages would just support them, they made formal complaint of the change, and demanded an advance of compensation. Thus the multiplex and ever-varying conditions of temperature, air, and exercise, joined with the diverse influences of age, sex, constitution, temperament, and habit, conspire to determine the necessity for food in each special case.

764. **Diversities in Digestion and Diet.**—There are also wide differences among different persons in point of ability to digest and assimilate food. We meet with one class—types of robust health, with sound, vigorous systems, accustomed to much exercise in the open air, and who take all kinds of food, caring only that there shall be enough. They never suffer the slightest inconvenience from what they eat, and seem indeed to be unconscious of having any stomach or visceral organs. All discriminations among aliments, as digestible and indigestible, with suggestions and precautions concerning diet, fall upon the ears of such as without signification. On the other hand, we behold the dismal group of dyspeptics, horribly conscious of their digestive arrangements, and to whom the whole world of aliment is turned into a perennial fountain of misery. Between these two extremes there are all degrees of digestive power and gastric susceptibility. Again we notice great diversities in plans of diet among those with healthy digestions. This state of things makes difficulty in fixing upon terms to describe different sorts of diet. *Low* diet, for example, is applied to a combination of food that yields less blood and strength than usual, while a *high* or *generous* diet tends to produce a contrary effect. But it is obvious that a diet which would be, to all intents and purposes, *low* and *spare*, to a hearty meat-eater, might be *high* and *generous* to a strict vegetarian. To be able, therefore, to pronounce any particular diet *abstemious* or *full*, we must understand the preceding dietetic habits.

765. **Daily requirement of Food.**—These facts make it apparent, that all rules of diet are necessarily so general as to be of little service, until modified to suit the peculiar circumstances of each individual. Instead of blindly submitting ourselves to any scheme of dietetic directions, we should exercise an independent judgment, studying carefully our own constitutional peculiarities, analyzing our conditions,

and freely revising all rules before reducing them to personal practice. We cannot fix the precise quantity of food required to be consumed. Where men are dealt with systematically in large numbers, as the inmates of hospitals, soldiers, &c., it becomes necessary to establish diet scales, that is, to apportion to each person his due allowance of food by weight and measure. The following is the diet scale of the U. S. Navy: *Three days in the week;*—pork, 16 oz.; beans or peas, 7 oz.; biscuit, 14 oz.; pickles or cranberries, 1 oz.; sugar, 2 oz.; tea, $\frac{1}{4}$ oz.;=40$\frac{1}{4}$ oz. *Two days in the week;*—beef, 16 oz.; flour, 8 oz.; dried fruit, 4 oz.; biscuit, 14 oz.; tea and sugar, 2$\frac{1}{4}$ oz.; pickles or cranberries, 1 oz.;=45$\frac{1}{4}$ oz. *Two days in the week;*—beef, 16 oz.; rice, 8 oz.; butter, 2 oz.; cheese, 2 oz.; biscuit, 14 oz.; tea and sugar, 2$\frac{1}{4}$ oz.; pickles or cranberries, 1 oz.=45$\frac{1}{4}$ oz. These numbers are valuable as near expressions of the wants of large bodies of men, under given circumstances; but they are of small service as dietetical guides to individuals.

766. **Regulating the Appetite.**—We are left, therefore, in this matter entirely to individual discretion. Nature's guide is the appetite, but we must be cautious not to misinterpret its indications. In what hunger exactly consists we cannot tell. But the feeling seems to depend less upon the immediate state of the stomach (in respect of fulness or emptiness), than upon conditions of the general system. Hence the swallowing of food, although an immediate relief of hunger, does not at once extinguish the appetite. If therefore we eat slowly, prolonging the meal with deliberate and thorough mastication (634), time is given for the system to become conscious, as it were, of the progress of the supply, while the sense of quiescent satisfaction indicates that sufficient food has been taken, and that we should cease eating. If, on the other hand, we neglect these monitions, bolting the alimentary mass, and driving on to repletion, we incur the double evil of over-eating, and of taking our food in a crude, half-prepared state. To obtain that command of appetite which shall enable us to abstain before we reach satiety, is every way most desirable, both as a means of preserving health, and of regaining it when lost.

767. **Frequency and times of Eating.**—Systematic recurrence is the order of nature, observed every where, alike in the timing of melodious sounds, the rhythmic beats of the heart, the measured respirations, the coming and going of light, the ocean's ebb and flow, seasonal revolutions and planetary periodicities. The arrangement of regular times for meals, harmonizes, therefore, with the universal policy of nature, and is, moreover, of the highest social convenience. Yet it is impos-

sible to subject all to the same regulations of time. Dr. Combe remarks: "The grand rule in fixing the number and periods of our meals is, to proportion them to the real wants of the system, as modified by age, sex, health, and manner of life, and as indicated by the true returns of appetite." As the blood is usually most impoverished after the eight or ten hours' fast of the night, breakfast should be early (768). The stomach is usually vacated of its nutritive contents in about four hours after eating, but it may be an hour or two later before the blood begins to call upon it for a renewed supply. Persons engaged in active labor, in which bodily expenditure is rapid, of course require to eat more often than the indolent and the sedentary; and children need nourishment oftener than adults. But too long abstinence, especially if the digestive power be not strong, sharpens the appetite, so that there arises danger of excessive eating. Some avoid luncheon for fear of 'spoiling the dinner,' whereas the thing they most need is to have it spoiled. Where the intervals between the meals are so long as to produce pressing hunger, something should be taken between them to stay the appetite and prevent over-eating. Late and hearty suppers are to be reprobated. Active digestion and sleep mutually disturb each other, as at night the exhalation of carbonic acid is slowest, and tissue changes most retarded, the overloaded blood is not relieved, and invades the repose of the brain, producing heavy, disordered dreams, and nightmare, followed by headache and ill-humor in the morning. Still there is the opposite extreme, of sitting up late, and going to bed wearied, hungry, and with an 'indefinable sense of sinking,' followed by restless, unrefreshing sleep. A little light nourishment in such cases, may prevent these unpleasant effects. Custom has fixed the daily number of meals at from three to five; probably three is the smallest number that consists with well-sustained vigor of the system; four or five may be unobjectionable, the amount of nourishment taken each time being less. The essential thing is, regularity in each case, in order that the digestive glands may have time to prepare their secretions (641).

768. **Rest before Meals.**—We should not take our meals when tired out, or much fatigued. The stomach participates with the other parts of the system in the exhaustion, and is thus unfitted for the performance of its proper and active duties. If there has been severe exercise, either of body or mind, a short interval should be allowed for repose, or half an hour may be appropriated to any light occupation, such as dressing, before sitting down to dinner. It is questionable if much exercise before breakfast be generally proper. When we rise in

the morning, the system has passed the longest interval without food, and is at the lowest diurnal point of weakness from want of nourishment. It is well understood that the body is more susceptible to the morbid influence of colds, miasms, and all noxious agencies, in the morning before eating, than at any other time; and those exposed to the open air before getting any thing to eat, in aguish regions, are infinitely more liable to be affected than those who have been fortified by a comfortable breakfast. Cases may be quoted, undoubtedly, in which early exercise has produced no injurious results—perhaps even the contrary. Yet in most instances, especially if the constitution be not strong, breakfast should follow shortly after rising and dressing, before serious tasks are attempted. Dr. COMBE justly observes, that in "boarding schools for the young and growing, who require plenty of sustenance, and are often obliged to rise early, an early breakfast is almost an indispensable condition of health."

769. **State of Mind during Meals.**—We have before seen how mental and passional excitement disturb appetite and digestion (685). The brain and stomach are profoundly sympathetic. Morbid states of the stomach often so disturb the brain as to throw a pall of gloom over the mind, or destroy its equanimity, as we often see in dyspeptics, while any mental tension or discord interrupts the gastric functions. Food has been rejected from the stomach, unaltered, several hours after it was taken, under the dread of an impending surgical operation. During meals, therefore, every thing like intense mental exercise should be avoided, yet the mind ought to be lightly occupied, as in cheerful, exhilarating conversation upon passing topics. A flow of sprightly or sportive talk, that may agreeably engage the attention, and thus protract the meal, is not only most pleasant at table, but is of solid physiological service. This explains an observation of Dr. CHAMBERS. "It is very common to hear bachelors complain that when they dine in company, their dinner gives them no trouble; they swallow all sorts of imprudent food, and feel no more of it, while a solitary meal at their club, on the plainest meat, is digested with difficulty and pain."

770. **Exercise after Meals.**—When any portion of the body is strongly exercised, the whole system is taxed to sustain it. There is an unusual determination of blood to the excited part, with, of course, a corresponding deficiency in other parts. The case of the two dogs is well known, both of which had taken a hearty meal, one being then left at rest and the other put upon the chase. After a short time they were both killed, when digestion was found far advanced in the one at rest,

while it was not even begun in the other. The vital force required to promote digestion was diverted entirely to the muscular and nervous systems. There is some conflict of opinion as respects the propriety of exercise after a hearty meal, such as dinner. Dr. BEAUMONT says, "From numerous trials, I am persuaded that moderate exercise conduces considerably to healthy and rapid digestion. The discovery was the result of accident, and contrary to preconceived opinions." Dr. COMBE, on the other hand, observes "that active exercise immediately after a full meal, such as is generally taken for dinner, is prejudicial to its digestion, seems to be proved by daily and unequivocal experience." We conclude that physiological indications, the widest experience, and the analogies of nature, concur to suggest rest for a time, or very gentle exercise, as most advisable.* There is clearly a depression of the general functions of the body, with a tendency to sluggishness and repose. Inclination to rest after eating, seems to be a universal instinct of the animal kingdom. To those who are drowsy and

* "Reading has been too much overlooked of late as a bodily exercise, and the benefit has been doubted, because of the awkward manner in which it is done. Look at a Greek or Roman representation of a man speaking or reading; he is standing up, or sitting back with the chest thrown well forward and dilated, the nostrils open, and the shoulders flatter and more erect than when walking. The artist's model evidently has the lungs filled with air, and the diaphragm at rest, so that full play is given to the elastic cartilages of the ribs. The man is rolling out his words really *clare*, as CELSUS has it, comfortably to himself, and agreeably to his hearers. Observe as a contrast many a modern reader or orator; his constrained attitude recalls rather the architectural incongruities of Gothic art, expressing, perhaps, the earnestness and self-denial which that style may be held to indicate, but certainly not wholesome ease. The head is bent forward, a stiff neck-cloth compresses the windpipe, the lungs are emptied, and the words are squeezed out by an effort of the diaphragm and abdominal muscles, which makes the listener fancy he can almost hear them creak with the strain. They are used at an enormous mechanical disadvantage, and the nervous energy of the whole trunk is foolishly exhausted. Hence, reading and preaching, instead of being a relief to gastric derangement, are nowadays found actually to produce it. The clergyman's sore throat and dyspepsia have often been traced to their professional work, and that which might have been a cure has become an aggravation. There was, some years ago, a quack in the Isle of Wight, who used to treat clergymen very successfully, under a promise of secrecy. His method was simply to teach them to keep the chest inflated, by breathing in only through the nose, and to allow it to empty itself by the elasticity of the cartilages as the patient spoke. This plan entails the habit of straightening the windpipe, sitting or standing upright, and throwing the shoulders back; in fact, of assuming the attitude which I have described as a model for the reader, and is for that reason found practically beneficial. If patients can sing, they possess a part of the Materia Medica very valuable to their digestion. They will seldom require the hints above given, for most leading masters have found the necessity for teaching their pupils a rational attitude, and the ordinary time for exercising the art is the hour after the meal that most requires attention. It is striking how rarely powerful singers suffer from gastric derangement."—(DR. CHAMBERS.)

inclined to take their *siesta*, or after-dinner nap, we may suggest that it is better to sleep upright in a chair than to repose on a sofa or bed. In the former position the sleep is generally short, and never very profound; but when the whole body is recumbent and the stomach full, the sleep is heavy, prolonged, and unrefreshing.

771. **Effects of Excessive Eating.**—The consequences of uncontrolled indulgence of the appetite manifest themselves variously. The immediate result of over-eating is lethargy, heaviness, and tendency to sleep. The effect of persisting in the habit will depend upon numerous circumstances. In a healthy system, with good digestion and much active out-of-door exercise, bad results may not follow from the freest use of plain food. In other conditions the burden may fall upon the overworked digestive organs, which are irritated by the presence of the excess of food which they cannot appropriate. If digestion be strong, an excess of nutriment may be projected into the blood, overloading the circulation. If food is not expended in force, the natural alternative is its accumulation in the system, increasing the volume of muscle and tissue, and swelling the deposit of fat. Degeneracy of the structures, mal-assimilation of nutritive material, increased proneness to derangement and diseased action, and various unhealthy conditions, may be induced by the habitual employment of too much food. It is either transmuted into fat and flesh, or into pain and disease. Yet it is very common to charge upon *quantity* the evils that flow from *quality* in diet. Injury may spring from hearty indulgence in a rich, concentrated, and various diet, which would not flow from the most liberal use of plain and simple food. 'Dine upon one dish, and in that consult your taste,' is an excellent motto.

772. **Effects of Insufficient Nutrition.**—The blood is the stock of material on hand, from which the supplies of the constantly wasting system are withdrawn, and this stock is but small. It contains dissolved only about one-eighth of the dry matter of the body, so that the strength can be sustained only a very short time without external supplies. Yet when food is withheld, life holds its ground against extensive changes. An animal does not die of starvation till it has lost two-fifths of its weight and more than a third of its heat. Yet, so important is the prompt and regular ingestion of aliment, to keep the system up to the par of its activity, that even transient interruptions produce serious disturbance. As the demand for nourishment is the prime necessity of our being, taking precedence of all other needs, if the supply be suspended, the clamors of the system for food rise at once above all other wants. Until hunger is appeased, there is disquiet; the

mind traverses with less than its usual freedom, the temper is more easily started, and sleep fails to invigorate as usual. There was shrewd, practical wisdom in the warning of Cardinal De Retz to politicians, never to risk an important motion before a popular assemblage, however proper or wise it might be, just before dinner. Of the effects of insufficient food Moleshott speaks as follows: "There is another instinct by which the vigor of the mind is vanquished in a more melancholy way. Hunger desolates head and heart. Though the craving for nutriment may be lessened to a surprising degree during mental exertion, there exists nothing more hostile to the cheerfulness of an active, thoughtful mind, than the deprivation of liquid and solid food. To the starving man every pressure becomes an intolerable burden; for this reason, hunger has effected more revolutions than the ambition of disaffected subjects. It is not, then, the dictate of cupidity or the claim of idleness which prompts the belief in a natural human right to work and food."

773. **Diet and the Capacity of Exertion.**—There are evils also in the opposite extreme of a too restricted diet. Our strength and power of accomplishment is derived from the food we consume, and for high and sustained effort there is required a strong and generous diet. We cannot have something for nothing. Large exertion, physical or mental, involves active physiological change, and hearty eating, to sustain it. The distinguished and discriminating President of one of our largest collegiate institutions remarked to us, that many students required to be encouraged to freer living. Urged to economy by limited resources and misled by the partial views of those who recommend low, abstemious diet as favorable to clearness of thought, they adopted a scale of nutriment insufficient to sustain the powers of nature in vigorous and protracted exercise. Existence can undoubtedly be maintained on a very small amount of food, but we are not concerned to know what that minimum of nourishment may be, as bare, inert, passive existence is no object. Life is of but little value except in its *purposes*, and man is only a *man* in his capability of executing them. Cornaro, the Venetian, the Prince of ascetic heroes, lived to a great age on 12 oz. of food, chiefly vegetable, per day, and 14 oz. of light wine. But he passed "a sort of vegetable life in his palace and gondola," without stress or buffet, while a mere lawsuit is said to have carried off two of his brothers who attempted the same style of living. "Dr. Stark, of London, tried similar experiments, and got on pretty well so long as he had nothing to do besides weighing himself, but when he came to undergo a contested election for St. George's Hospital, it killed him

outright. If the body is to be exposed, as it is in all modern civilized life, to sudden extraordinary demands, it must be prepared for them by being habituated to take in rather more than is ordinarily required."—(Dr. CHAMBERS.) It is charged upon the Americans that they are enormous feeders; probably they eat too much; but where else upon the globe is there such general activity, bodily and mental?

774. **Order and Variety in Diet.**—Our nature was made for variety. The differences of complexion, cast of countenance, expression and figure constantly presented to us in the human form, are infinite. The objects about us are endlessly and namelessly diversified, always harmonious, yet ever changing into new relations. We gather from this, that in habits and experience, man is not designed to be the slave of a mechanical routine, nor to fall into tame and spiritless repetition. Of all the systematic degradations to which he is subject, the lowest is that of the soldier, who has taken formal leave of his independent manhood, who starts at the tap of the drum, belongs somewhere in a row, and lives only to be drilled and messed at the arbitrary dictation of his superiors. In nature, we behold inflexible order working out eternal variation; and so in life, methodized habits should give rise to never-ceasing diversities. As respects diet, the materials prepared for us, although marvellously simple in composition and adaptation to our needs, are wonderfully various in form and gustatory properties. We have the widest and freest choice of means to accomplish the same physiological end. Nature thus solicits us to enjoy the bounty of her resourses, which we should wisely do, not tempting the appetite with a parade of culinary enticements, but restricting the dishes at each meal, and agreeably varying them at successive times of eating.—Prof. MOLESHOTT, after insisting that all food partakes somewhat of the nature of a stimulant, has the following observations: —"And as the uniformity of the stimulant, even if repeated at longer intervals, is prejudical to its effects; a regular arrangement of dishes, repeated certain days every week, is a custom not to be commended. If a stiff regularity only too clearly betrays a commonplace narrowness of mind, such a regular repetition becomes a source of petty formalism, insensibly, but all the more dangerously, repressing the free movements of the mind. Whoever has watched himself with attention, will often enough have experienced how the refreshing and stimulating effect of a walk is evidently lost if taken for a long time daily at the same hour. It is the same with uniformity in meals; and while the ancient physicians used actually to assert it to be useful sometimes to throw the body out of order, in accordance with this

doctrine, it is perfectly true that an inflexible regularity of life is by no means compatible with a genial freedom."

775. **Diet and Corpulence.**—The undue accumulation of fat is promoted by many causes. Privation of active exercise, too much indulgence in sleep, indolent, sedentary habits, and want of thought, favor obesity;—restless animals and industrious men are seldom inconveniently fat. The free use of an oily, starchy, or sugary diet, dispose to fattening, as also alcoholic liquors and the absorption of watery fluids, either by much drinking, frequent warm baths, or even breathing damp air. It is also frequently caused by defective digestion. There may be want of gastric power to manage the nitrogenous matters, the muscular fibre escaping from the stomach half dissolved. As a moderate diet thus proves insufficient, it is instinctively increased, and fatty bodies being more easily assimilated than the albuminous, a surplus of it is lodged in the system. The excessive increase of fat must be regarded as a disease, and often involves the constitution in much disorder. In the truly healthy organization, there is a perfect correspondence in capacity and power, between the circulation through the lungs and that of the general system (283); but where the fat deposit becomes largely increased, the extension of the minute blood-vessels to maintain the extra nutrition, destroys the equilibrium; the lung circulation is inadequate to its full duty, the carbonic acid is not perfectly excreted, the blood becomes venous, the circulation is retarded, producing congestion, with frequent dilatations and degenerations of the heart. The diet best fitted for corpulency, is that containing the least oil, starch, or sugar. Very light meals should be taken at times most favorable to rapid digestion, and should consist of substances easy of solution and assimilation. The time of meals should be fixed at an early hour in the day, before exertion has rendered the powers of the alimentary canal languid. Breakfast should consist of dry toast, or still better, of sea-biscuit, and if much active exercise is intended, a piece of lean meat. Dinner at one, on meat with the fat cut off, stale bread or biscuit, and some plain boiled macaroni or biscuit pudding by way of a second course.—(Dr. CHAMBERS.) Lean meat is a good diet for the aspirant after leanness;—carnivorous animals are never corpulent. In connection with proper diet, vigorous and systematic exercise is essential. Sometimes there is an accumulation of fat, where the amount of aliment taken is less than natural. Such cases are difficult to remedy by exercise, as the quantity of food taken is too small to sustain muscular strength.

776. **Diet of Infancy.**—We have stated that nature prescribes the

infant's diet in the composition of its mother's milk; but nature is sometimes defeated in her intention, as the mother's diet controls the milk-secretion both in quantity and quality. If her food be scanty, or low and light, the infant will be imperfectly nourished. The lactic secretion requires to contain its due proportion of casein, sugar, oil, and phosphate of lime; and to produce these copiously, a varied nutritious diet of good bread, meat, milk, eggs, and potatoes, is required. The aliment which the mother furnishes to her child is more richly nutritive than that which she retains for her own nourishment. She should avoid indigestible substances, and especially take but little vinegar or acid fruits, as these both diminish the amount of milk and render what there is less nutritious. The nursing mother may with great advantage make free use of milk itself, as it furnishes, ready formed, the substances she is required to impart. Should there be tendency to acidity, it may be corrected by mixing the milk with a mild alkali, such as one-fourth or one-fifth of its bulk of soda water. It becomes often necessary that children should be surrendered to *wet nurses.* As the composition and consequent physiological effects of milk gradually change in the successive months after the child's birth, it is important that the ages of the children, both of the mother and wet-nurse, should be as nearly as possible the same. That nature, temper, and character are communicated by her milk, from the mother to the nursing child, is not an idle prejudice. Not only do bodily circumstances of health affect the lactic secretion, but conditions of the mind and passions also. A paroxysm of anger may pervert and even poison the fountain of life; "and there is no thought more natural, than that on the breast of its mother the infant may imbibe together with its milk, her nobleness of mind." When the exigency occurs, therefore, the selection of wet-nurses is a matter of much importance. If they have been accustomed to plain, substantial diet, it is highly unwise to pamper them with delicacies, as is sometimes done in affluent families, indigestion and bad bodily conditions being very liable to ensue. As respects the use of spirits under these circumstances, Dr. CHAMBERS, himself no advocate of abstinence, has the following remarks. "Nursing women are desired to drink an unusual quantity of porter, wine, bitters, and what not, till they get bloated, thick-complexioned, stupid, and dyspeptic. The reason of this is, that alcohol and other ingredients, in such a diet, arrest metamorphosis, detain in the system the secretions we want to flow out, and fill those which do flow out with effete matter. If the constitution of the mother is robust enough to stand this bad usage,

and still afford the due quantum of milk for her child, yet that must be of inferior quality to what she otherwise would have made, and the innocent consumer suffers." The milk of the cow differs so considerably from that of the mother, that it should be corrected if it is to be given to the infant. This is done by adding a third or a fourth of water, and about 1·25th its weight of refined sugar; it should be warmed to the temperature of the body, 98°. To this, solid substances may be gradually added, as wheaten bread or boiled farina (445), but not arrowroot, tapioca, sago, or rice, upon which many children are fed to death. These are not complete nutriments, and are incapable of promoting the growth of either bones or flesh (746). Even after weaning, soft mixtures of good bread with milk and sugar, or with the juices of meat; also the more readily digestible roots and vegetables, together with soups prepared from the meat of young animals, may be considered the best food. After the teeth are cut, meat and bread in their simple form may also be given. Aliments difficult of digestion, fat meat, heavy bread, rich pastry, unripe fruit, leguminous seeds, and heating condiments are carefully to be avoided for children.

777. **Diet of Childhood and Youth.**—Besides the maintenance of activity, the diet of this period must be such as to harden, strengthen, and expand the system. The muscles increase in fibrin and firmness, tissues are developed and strengthened, and the gelatinous model of the bones is solidified and enlarged into a strong skeleton by the gradual deposit of bone-earth. With these changes there is also a slowly augmenting activity of bodily transformation, the excretion of carbonic acid by the lungs, and of urea by the kidneys, increasing in amount up to the twenty-fifth or thirtieth year. The demand for food is therefore more peremptory during the growing time of youth than at any portion of subsequent life. As regards the indulgence of the appetite at this period, perhaps there is no better guide than the indications of nature. So children have *plain* food, if healthy and active, they will hardly eat sufficient to injure themselves. It is not right to subject the young to a regimen adjusted to the adult; they require more nutritious food, and to satisfy the appetite oftener. Something to eat in mid-forenoon and mid-afternoon will often be necessary, but the thing should be done strictly upon system, as the habit of eating irregularly, at every capricious call of appetite, is wrong and injurious. Yet, though the diet of youth should be nutritive and strength-imparting, it is of the first necessity that it should be plain and unexciting. Luxurious stimulating food, charged with condiments and

nerve-provocatives, gives rise to a morbid precocity of instincts, thoughts and actions, and helps to explain the unhealthy prematurity, the slender figures and pale faces of boys and girls brought up in towns.

778. **Diet of Middle Life.**—When maturity has been reached, there comes a period, varying in duration, but extending perhaps from the ages of 25 to 45, in which the bodily exchanges are in equilibrium—the expenses and receipts of nutrition are balanced, and the individual neither gains nor loses weight. No portion of the food is now to be appropriated as heretofore in growth; it may all be devoted to exertion. It is the time of maximum power, the effective working period of life. The diet should be varied and strong, but of course ought to be modified in accordance with the activity, constitution and various circumstances. For hard, exhausting labor, brown or lean meat, the leguminous seeds, bread, and an admixture of vegetables may be employed. It can hardly be necessary to add in the light of the principles of nutrition which have been established, that fat pork is generally much over-estimated by laborers; it is the blood-producing beans and bread with which it is always associated that chiefly imparts the strength. It has been sufficiently pointed out that persons in light sedentary occupations, brain-workers and idlers, should avoid those more indigestible substances, and while reining in the appetite, or at all events, not spurring it, should live upon a diet of the most easily digestible substances.

779. **Diet of Advanced Life.**—As age comes on, the nutritive conditions of youthhood are reversed, the body can no longer digest and appropriate sufficient to meet its destructive losses, and there is a decrease of strength and weight. The tissues shrink, as we see in the shrivelled hands and wrinkled brow, the hair is changed in composition, the bones become more earthy and brittle, the cartilages ossify, there is a general diminution of fat, and a loss of fluids in all parts except the brain, which becomes more watery. The stomach participates in the general decline, its diminished and weakened juices becoming less capable of dissolving the necessary food; the circulation is retarded, and the general vitality lowered. As the solvent powers of the stomach begin to be enfeebled, and the appetite becomes languid, elderly people should be admonished to exercise care in selecting food, and not waste the power they have on refractory indigestible aliments. Young and tender meats, strong broths, milk, light, well-baked bread, and tender succulent vegetables, tax the digestive organs least. Nor should they commit the error of supposing that the waning powers

of advancing life can be sustained by increasing the quantity of food eaten. Dr. Cheyne remarked more than a hundred years ago, "Every man after fifty ought to begin to lessen the quantity of his aliment; and if he would avoid great and dangerous distempers, and preserve his senses and faculties clear to the last, he should go on every seven years abating gradually." When hints like these are neglected, and persons persist in a high and hearty diet, keeping up a plethoric state of the system, serious and fatal consequences often ensue. The blood-vessels of the brain are not only weaker than those of any other part of the body, but they derive no support as other vessels do from the elastic pressure of surrounding muscles. In the imperfect nutrition and growing debility of advancing age, these vessels participate, so that with over-fulness there arises liability of their giving way, as in brain congestion or apoplexy.

PART FIFTH.

CLEANSING.

I.—PRINCIPAL CLEANSING AGENTS.

780. **Chemical Principles Involved.**—Dirt has been laconically defined as 'matter in the wrong place'; its removal constitutes 'cleansing.' The action of cleansing agents, and the management of cleansing processes, depend upon the properties of solvents and the operations of solution and decomposition, and therefore involve questions of chemistry. We have had frequent occasion, in the preceding pages, for the aid of this science in elucidating the phenomena of the household, and we shall none the less need a knowledge of it to understand the present subject. The considerable space given to aliments makes it necessary to restrict our treatment of this topic within narrow limits.

781. **Water as a Cleansing Agent.**—This is the most important and universal of the agents of purification employed by art. It is so essential to life, that where man dwells it is always found, and is supplied by the hand of nature with a copiousness equal to its necessity and value. Water cleanses by its mechanical action in carrying away dirt and impurities, and also by its power of dissolving them. While it possesses the property of dissolving a great number of substances, it is at the same time so mild and neutral as not to injure the objects to which it may be applied.

782. **Cleansing of Water.**—But before water can be used for cleansing purposes, it may *itself* require to be cleansed. We have already stated that it is liable to many forms of impurity. It is often desirable to remove these contaminations by artificial means, and thus make the liquid purer, which may be done in various ways. The foreign substances of water are of two kinds; *first*, finely divided earthy matters, as sand, clay, lime, &c., and particles of vegetable and animal substances, as of decayed leaves, decomposing wood, insects, &c., diffused

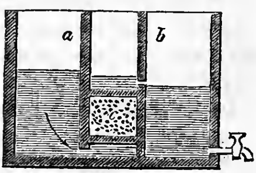
through the liquid and mechanically suspended in it, causing it to appear more or less turbid or cloudy; and *second*, various *dissolved* substances which contaminate the water, while it is yet clear to the eye and *apparently* pure.

783. **Purification by Subsidence.**—The first sort, or mechanical impurities, if the water is kept perfectly still, will mostly subside, forming sediment; the heavier particles falling first, and the finer afterward. It is wisely arranged that there are but few substances of exactly the same specific gravity as water; if there were, this fluid would scarcely ever be clear. But there are many particles which find their way into water that are so near its precise weight, that they remain long suspended, and hence we must resort to other means for their removal.

784. **Purification by Filtering.**—Water strained or leached through soils and sand-beds comes out free from mechanical contaminations; hence if made to percolate through artificial sand-beds, it may be delivered clear. A cistern may be divided into two compartments by a partition which does not reach quite to the bottom. In one of the divisions is put layers of sand, of different degrees of coarseness, the finest being at the bottom. The water is poured into these apartments, trickles through the layers, its impurities are detained, and it comes out into the other division clear. After a time the sand gets clogged with sediment, and needs to be renewed.

785. **Upward flow of Water through Filters.**—Through nature's filter-beds water *ascends*, rising to the surface in springs, &c. This is better, as their weight tends to oppose the ascent of the impurities which are more likely to be left behind. The arrangement may be made available in many ways; the principle is illustrated in Fig. 124. In the cistern or vessel the partition *a* does not reach quite to the bottom.

124.



The middle division has a perforated bottom of metal or wood, above which is placed a layer of sand, and upon that a layer of charcoal. In the partition *b*, and above the filter, is an aperture through which the filtered water passes, and is drawn off by the faucet. Where rain water is to be preserved for household use (380), an underground cement tank should be constructed to store it, and a filter similar to the one described placed above, through which the water from the roof should flow to the reservoir. Filters may be cleansed by reversing the direction of the water through them. The principle of filtration is

so simple that any vessel can be made to answer for it, tall ones being preferable to shallow. A box, cask, jar, or flower-pot may, with the least ingenuity, be made to serve the purpose. Besides sand, porous stone, pounded glass, woollen cloths doubled thickly, sponge, &c., are used for filtering. But by far the most valuable agent for the purpose is charcoal. Its purifying action goes much further than merely straining out mechanical impurities; it acts powerfully to absorb and destroy offensive gases (811). The foulest ditch water made to pass through a layer of charcoal, comes out sweet, clear, and bright. Animal charcoal, derived from burnt bones, is more powerful than wood charcoal, owing, perhaps, to the fact that its mineral matter acts as a divisor, separating the particles and exposing a larger surface.

786. **Impurities in Solution.**—But the dissolved impurities of water cannot be removed by filtering; it is more difficult to separate these. By vaporizing, water leaves its impurities behind. Steam conducted away and condensed in a separate vessel, produces distilled water, which is its purest form. A tube of copper, glass, or gutta-percha, connected with the spout of a tea-kettle, and surrounded by cloths kept saturated with cold water, affords a rude but convenient means of preparing the purest water. The removal of dissolved impurities by other means depends upon the special nature of the dissolved substance. Thus, carbonate of lime or limestone, is dissolved in but a small degree by pure water, but water containing carbonic acid dissolves it freely, in proportion to the amount of the contained gas. It has been found that one gallon (70,000 grains) of *pure* water will not dissolve more than two grains of carbonate of lime. But by the addition of carbonic acid, it acquires the power of dissolving 10, 20, or 60 grains, as the case may be. The number of grains contained in a gallon has been adopted to express the '*degree of hardness;*' thus, 10 grains would correspond to 10 degrees of hardness, 20 grains to 20 degrees, and so on. By boiling, the carbonic acid is driven off, the carbonate of lime precipitates or falls, and the water is softened. This is the source of the thick *fur* which gradually accumulates on the inner surface of tea-kettles in limy districts. But *all* the carbonate is not at once precipitated when the water is raised to boiling; it may, indeed, take two or three hours of brisk boiling to separate all the lime that is capable of being thus removed. It has been found that water of 14 degrees of hardness lost two degrees when merely made to boil; boiling for five minutes reduced the hardness to 6 degrees, and for a quarter of an hour to a little more than four degrees. There is, therefore, reason in the antiquated habit of letting the tea-kettle boil

for some time before the tea is made; it softens the water (533). We may relieve water of one impurity by adding another, and the exchange is often desirable, as when we wish to convert hard water into soft. If water be hard from carbonate of lime, the addition of a little caustic lime (wet to the consistence of cream) will absorb the excess of carbonic acid, and the insoluble carbonate will separate; the danger is that there will be an excess of caustic lime, so that the softened water will be corrosive. If water be hard from sulphate of lime, it is softened by the addition of potash, or soda, which decomposes the lime compound combining with its sulphuric acid. The new compound is not decomposed by soap (794).

787. **Alkaline Substances for Cleansing.**—But there are many substances upon which water will not act; other agents must therefore be called in to aid it. The alkalies, potash, soda, and ammonia, are most powerful chemical bodies, decomposing a great many different compounds, especially every thing of a vegetable and animal nature. But they are far too strong for ordinary use, as they not only remove dirt and impurities, but corrode and injure the fabrics or objects which it is desired to cleanse. The alkalies, when pure, from their hot, corrosive, disorganizing nature, are called *caustic*. But we do not meet with pure alkalies; the ever-present carbonic acid of the air combines with them, forming carbonates. But as the carbonic is a very weak acid, it only neutralizes them in a partial degree, their carbonates being very powerfully alkaline. When the alkalies are commonly spoken of, it is their *carbonates* that are meant. The alkaline carbonates dissolve readily in water, forming *ley*. Soda is of a weaker nature than potash, less liable to injure, and therefore better fitted for detergent uses. Ammonia is an alkaline gas, called the *volatile alkali;* it is adapted for use in all cases where a gaseous alkaline agent is required. Its common form, however, is *aqua-ammonia*, or solution in water, which absorbs a large amount of it.

788. **The Alkalies Modified—Soap.**—Alkali is the principal agent of cleansing in most domestic operations, the chief question being how to restrain and regulate its power. Soap is an artificial compound of alkali with the acids of oil or fat (195), by which the alkaline energy is to any required degree masked or subdued. The theory of soap-making (*sapanification*) is, that the alkalies decompose the oils, setting free their basic part or glycerin, which is lost, and combining with other acids, forms alkaline salts; soap is therefore really a salt.

789. **How Soap is made.**—The alkalies require to be in a caustic state, which is produced by dissolving them and passing the solution

(ley) through newly slaked lime, which takes away their carbonic acid. Soap may be made by the alkalies in their condition of carbonate, but just so far as the alkali is neutralized by the carbonic acid, it becomes useless for soap-making. In the caustic ley the fats are boiled, their glycerin is set free, and the fatty acids combining with the alkali, form soap, which exists as a solution in the water. To obtain it in a solid form, the solution is boiled down to a certain degree of concentration, when the soap ceases to be soluble, and rises to the surface in a soft, half-melted state. This being drawn off into moulds, cools, and forms hard soap. If soda ley is used, the soap may be separated from the water, in which it is dissolved, by adding common salt, which forms a brine and at once coagulates the soap. If potash ley is used, the addition of salt decomposes the potash soap, and forms a soap of soda.—(*Class-book of Chemistry.*)

790. **Hard and Soft Soap.**—Soaps are thus of two kinds, hard and soft, this condition being influenced both by the fat and alkali employed. The firmer and harder the fat, the solider will be the resulting soap. With the same alkali, therefore, tallow will make a harder soap than palm or olive oil, and stearic acid than oleic acid. But the consistence of soaps depends far more upon the alkali employed. Potash is very deliquescent, that is, has a strong attraction for water, so that when exposed it will absorb it from the air and run down into a fluid or semi-fluid state. The potash retains this water in the condition of soap, so that potash soaps are always liquid and soft. The hard soaps, therefore, all contain soda, those with tallow or stearic acid being the hardest. Potash soaps will not dry, but retain their soft, jelly-like condition, while some kinds of soda soap become so hard by drying that at last they can be pulverized.

791. **Water in Soap.**—Soap has a strong attraction for water, and may retain from 50 to 60 per cent. of it, and still remain in the solid state. Even when dry and hard, it holds from 25 to 30 per cent. of water. The customer is therefore interested to purchase old, dry soap, while the vender of course finds his advantage in selling it with as large an amount of water as possible; and hence often keeps it in damp cellars, in an atmosphere saturated with moisture, to prevent it from drying. The quantity of water contained in a sample is easily determined, by cutting the soap into thin slices, weighing, and drying at a temperature not exceeding 212°. It is impossible, however, in this way, to separate all its water. Its proportion of water influences the solubility of soap. Some dissolve so freely in washing as to waste rapidly when used, while others possess the opposite quality—as, for

example, "the small cubic mass of white, waxy, stubborn substance, generally met with on the washing stands of bedrooms in hotels, and which, for an indefinite period, passes on from traveller to traveller, each in turn unsuccessfully attempting, by various manœuvres, and diverse cunning immersions in water, to coax it into a lather." Hence, although, as a general rule, old, partially dried soap is preferable, yet it may be so dry and insoluble, as to involve too great labor in rubbing it into a lather; and to injure articles by excessive friction, with large chance of failure in the cleansing operation. Business competition, and the demand for low-priced articles compel manufacturers to furnish soaps with a large excess of water; but these cheap soaps may not be the most economical.

792. **Varieties of Soap.**—Common *yellow hard soap*, consists of soda with oil or fat and resin. Resin is a feeble acid, capable of combining with alkali, but neutralizing it less completely than oil, so that the compound or soap formed, is too powerfully alkaline. But when resin is worked with an equal or larger proportion of oil, it makes an excellent soap for many purposes. Genuine *castile soap* consists of olive oil, saponified with soda, and colored; that which is commonly sold under this name, however, is an imitation, made with common fatty materials. *Windsor soap* consists of tallow, a small proportion of olive oil and soda. Ordinary *white soap* or *curd soap* consists of tallow and soda. *Cocoa-nut oil* forms a soap that gives a strong lather. *Toilet soaps* are made with lard, almond oil, palm oil, olive oil, or suet, combined either with soda or potash, accordingly as they are desired to be hard or soft, and with as little excess of alkali as possible. They are colored and perfumed to taste. *Fancy soaps* are essentially common soaps, mixed with different aromatic oils and coloring substances, and diversified in form so as to suit the fashion of the day. Soaps are *mottled*, streaked or stained, by metallic oxides, chiefly oxides of iron; which can only be worked through the body of the soap, to give it the desired marbled appearance, *when it is of a certain consistence;* such soaps, therefore, cannot be charged with an excess of water. *Transparent soap*, is white soap that has been dissolved in alcohol; in addition to the detergent properties of the soap itself, it joins the alcohol, which is sometimes useful for cleansing purposes, and always harmless. But it wastes rapidly, and its advantages hardly compensate for its extra cost. Besides water and soap, the universal and most important agent, other substances are also employed for special purposes, which we shall notice in connection with their applications and uses.

II.—CLEANSING OF TEXTILE ARTICLES.

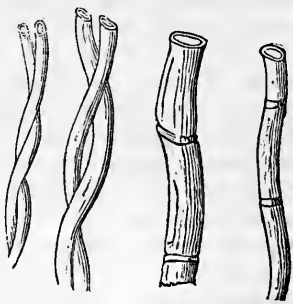
793. **Composition of the Dirt.**—The general principle of cleansing away all dirt, spots, and stains, consists in applying to them a substance which shall have a stronger attraction for the matter composing them, than this has for the cloth or surface to which it adheres. The dirt is to be dissolved, and hence for each special form of impurity we require, if possible, to find special solvents. It is a matter of chemical affinities. In cleansing textile articles, for example, we desire to remove the dirt without injuring the fibre of the cloth; and if it be possible, without disturbing the color. Alkalies are able to dissolve almost every thing that presents itself in the form of dirt, but they are too powerful, discharging colors and corroding the tissue. In soap, their activity is so restrained that they become generally available for cleansing purposes. The leading cementing constituent of dirt upon our garments, is some form of oily substance communicated by perspiration or contact of the skin, which is constantly covered by an oleaginous film. The oily, greasy basis of dirt, may be derived from many sources. But water has no affinity for oily matters in any form, and cannot dissolve them or alone remove them from any surface to which they may adhere. This is readily effected by soap, which being always alkaline, takes direct effect upon the grease, partially saponifies it and forms with it a compound which dissolves in water. The oily nature of the soap also increases the pliancy of the articles with which it is washed.

794. **Reactions of Soap and Water.**—Water is the common liquid vehicle of cleansing, and soap the agent resorted to, to render dirt soluble in water. The soap is either applied directly to the article it is desired to cleanse, or it may be first dissolved in water. As soap and water thus act jointly, it is proper to inquire as to their behavior toward each other. If the water be pure or soft, soap dissolves in it entirely; if it be hard, that is, if it contains sulphate of lime or magnesia, the soap, when added, instead of dissolving, curdles or is decomposed, and a new soap is formed, which contains lime instead of potash or soda. This new lime soap will not dissolve, and may be seen upon the surface of the water as a kind of greasy scum. It adheres to whatever is washed in it, and gives that unpleasant sensation called *harshness* when we wash our hands. Hence, with hard water, an excessive quantity of soap is required, while the operation is much less agreeable and satisfactory than with soft water. To test its quality of harshness, dissolve a little soap in alcohol and put a few

drops in the water it is wished to examine. If it remains clear, the water is perfectly soft; if it becomes cloudy or opaque, the water is ranked as hard, and according to the degree or density of the cloudiness, is the hardness of the water.

795. **Cotton, Linen, and Woollen articles.**—All textile articles are, however, not to be treated alike in cleansing. There is a radical difference in the structure of the fibre between woollen fabrics on the one hand, and cotton and linen on the other, which makes it necessary that they should be differently managed. Fig. 125 represents the straight smooth form of linen and cotton filaments, while Fig. 126 exhibits the toothed and jagged structure of woollen fibres. It is evident that these, by compression and friction, will mat and lock together, while the cotton and linen fibres, having no such asperities of surface, are incapable of any thing like close mechanical adherence. Hence, the peculiar capabilities of woollen fabrics, of *felting*, *fulling*, and shrinking, caused by the binding together of the ultimate filaments. We see therefore, the impolicy of excessive rubbing in washing woollen fabrics, and of changing them from hot to cold water, as the contraction that it causes is essentially a fulling process. The best experience seems to indicate, that woollen cloths should never be put into cold water, but always into warm; and if changed from water to water, they should go from hot to hotter. In the most skilful modes of cleansing, and preparing *delaines* for printing, the plan is, to place them first in water at 100° or 120°, and then treat them 8 or 10 times with water 10° hotter in each case. Some soak articles in warm water, to which a little wheat-bran has been added over night. The dirt is loosened, perhaps by a kind of fermentation. Soaking in weak soda-water is useful, but too free a use of alkalies shrinks the fibres of cloth and impairs the

Fig. 125.



Cotton fibres. Linen fibres.

Fig. 126.

Woollen fibres.

strength of the tissue. Resin-soap should not be employed to wash woollen, as the resin has the effect of hardening the fibres. Delicate textures, and especially white linen, should never be boiled in hard water. The carbonate of lime precipitated by boiling (786) is not only itself deposited upon the fabric, but carries down with it whatever coloring matter happens to exist in the water, and fixes it upon the fabric, imparting to it a disagreeable, unremovable dirty hue.

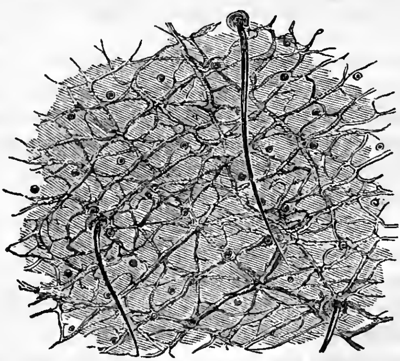
796. **Removal of Stains, Spots, &c.**—To do this without injury to the color or the fabric, is sometimes easy, frequently most difficult, and often impossible. Much may depend upon skilful and persevering manipulation; and although various agents, which we are now to mention, are oftentimes valuable, yet good soap, after all, is the chief reliance. *Grease-spots* may generally be removed by the patient application of soap and soft water, but other means are also employed. *Alumina*, or the pure principle of clay, has a strong attraction for fatty substances, and is much used in the form of fullers' earth, a fine-grained clay, which is prepared by baking and elutriation. It is used by diffusing a little through water, so as to form a thin paste, spreading upon the stain, and leaving to dry; the spot then only remains to be brushed. *French chalk*, a very resinous mineral, is also highly absorbent of grease. *Ox-gall* is an excellent and delicate cleansing agent. It is a liquid soda soap. It removes grease, and is said to fix and brighten colors, though it has a greenish tinge, which is bad for the purity of white articles. The application of a red-hot iron closely above a grease-spot often volatilizes the oily matter out of it. Brown-paper pressed upon a stain with a warm iron, will often imbibe the grease. Stains by wax, resin, turpentine, pitch, and substances of a resinous nature, may be removed by pure *alcohol*. The fats, resins, and unctuous oils, are dissolved by *essential* oils, as *oil of turpentine*. Common spirits of turpentine, however, requires to be purified by redistillation, or it will leave a resinous stain upon the spot where it is used. When pitch, varnish, or oil-paint stains have become dry, they should be softened with a little butter or lard, before using turpentine and soap. *Burning-fluid* combines the solvent powers of both alcohol and turpentine. Fruit-stains, wine-stains, and those made by colored vegetable juices, are often nearly indelible, and require various treatment. Thorough rubbing with soap and soft water; repeated dipping in sour butter-milk; and drying in the sun; rubbing on a thick mixture of starch and cold water, and exposing long to sun and air, are among the expedients resorted to. Sulphurous acid is often employed to bleach out colors. It may be generated at the moment

of using, by burning a small piece of sulphur in the air, under the wide end of a small paper funnel, whose upper orifice is applied near the cloth. Coffee and chocolate stains require careful soaping and washing with water at 120°, followed by sulphuration. If discoloration has been produced by *acids*, water of ammonia should be applied; if spots have been made by alkaline substances, moderately strong vinegar may be applied; if upon a delicate article, the vinegar should be decolorized by filtering through powdered charcoal. For iron mould, or ink stains, lemon-juice or salt of sorrel (oxalate of potash) may be used. If the stains are of long standing, it may be necessary to use oxalic acid, which is much more powerful. It may be applied in powder upon the spot, previously moistened with water, well rubbed on, and then washed off with pure water. It should be effectually washed out, for it is highly corrosive to textile fibres. The staining principle of common *indelible ink* is nitrate of silver. It may be removed by first soaking in a solution of common salt, which produces chloride of silver, and afterwards washing with ammonia, which dissolves the chloride.

III.—CLEANSING OF THE PERSON.

797. **Structure and Offices of the Skin.**—A glance at the curious and beautiful structure of the skin, and its important offices, will assist us to understand the causes and nature of its defilements. The outer layer of the skin (cuticle) is formed of albuminous cells, which, losing their liquid contents by evaporation at the surface, are flattened into exceedingly minute thin scales, of a horny, resisting quality, which serves as a protection to the sensitive or true skin underneath. The surface of the cuticle is constantly loosening, and wearing off in fine, powdery scales, which are replaced by new growths from below. Figs. 127, 128, exhibit the structure of the skin. It is an organ of

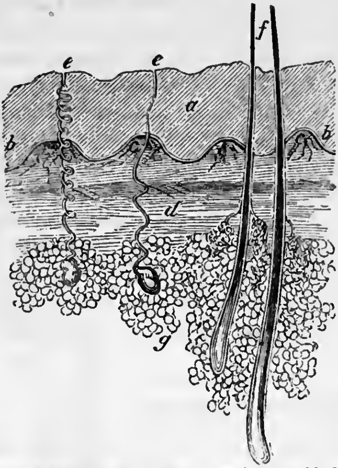
Fig. 127.



Surface of the cuticle greatly magnified, showing the pores and hairs.

drainage, with a double function; co-operating, with the kidneys, on the one hand, to relieve the system of water, and with the lungs on the other, to extrude its gases. The perspiratory tubes, which open through the cuticle upon the surface, forming pores, are spiral-shaped, as shown in the figure, and terminate in glands below. Prof. WILSON says, "I counted the perspiratory pores on the palm of the hand, and found 3528 in a square inch. Each of these pores being the aperture of a little tube, about a quarter of an inch long, it follows, that in a square inch of skin on the palm of the hand, there exists a length of tube equal to 882 inches. I think that 2800 might be taken as a fair average of the number of pores on the square inch, and 700 the number of inches in length for the whole surface of the body. Now the number of square inches of surface, in a man of ordinary height and bulk, is 2500; the whole number of pores, therefore, is 7,000,000, and the amount of perspiratory tube 48,600 yards, or nearly 28 miles." Twenty or thirty ounces of perspiration escape through these channels daily, and upon evaporating into the air, leave a residue upon the surface, of animal and saline matter, consisting of acids, alkalies, calcareous earth, &c.

FIG. 128.

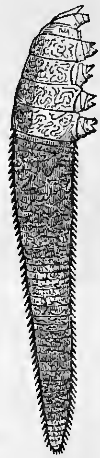


Vertical section of the skin, greatly magnified: *a* the cuticle, outer, or scarf skin; *b d* the true skin; *c* oil-tube and gland; *e* sweat glands and their ducts, the outlets at the surface being the pores; *f* hairs; *g* cellular substances.

798. **Impurities of the Skin.**—We have noticed the enormous exhaling and absorbing surface of the lungs (283), and the consequent danger to which we are exposed by the inhalation of foreign, poisonous substances, from the air. Evidently, if the skin were in the same condition, if its millions of little mouths were constantly and freely open to the air, the danger from absorption of infectious matter would be greatly heightened. But this consequence is wisely guarded against by a set of glands, whose special office it is to secrete oily matter to bedew the surface of the body. We notice that where this oily coating is in excess, it often gives an unseemly polish to the features;

while if it be deficient or absent, the skin is dry, harsh, and rough. Now this oleaginous pellicle, while offering no hindrance to *exhalation*, or the outward escape of waste matter, protects the system against too free absorption from without. It is this oily distilment, perpetually covering the cutaneous surface, that seizes upon all forms of dirt and impurity, cementing them into an adherent layer of dirt, comprising also the dregs of perspiratory evaporation, and the scales of scarf-skin just noticed. This crust of dirt may at length accumulate and consolidate, until it obstructs the pores, arrests free drainage, and thus seriously interferes with the functions of the skin, and the health of the body. As a consequence of the neglected state of this organ, the sedentary and irregular habits of refined society, the unctuous system of the skin becomes sluggish, and its actions torpid and irregular, and instead of the constant flow through the oil-tubes, their contents become dry, dense, impacted, and do not freely escape. They accumulate in the obstructed passages and form pimples. When those are squeezed between the finger nails, there issues a little cylindrical mass of white unctuous matter, which, when examined with the microscope, reveals a little animalcula, represented by Fig. 129. It is called by Dr. Wilson, who has studied its history and habitudes for six months at a time, *steatozoon folliculorum;* that is, the 'animal of the oily product of the skin.' These little personages are caterpillar-like, with head, feelers, four pair of legs, and a long tail. They are about the 1-45th of an inch in length, and always occupy the same position in the oil-tube, the head being directed inwards. The little mass shot out from the pimple may contain from two to twenty of them.

Fig. 129.



799. **Cleansing of the Skin—Ablution.**—As oil is the basis of the coating of dirt which daily concretes upon the skin, it is obvious that water alone is incapable of removing it. Soap is the proper skin-detergent. It partially saponifies the oil, rendering it miscible and soluble in water. The alkaline element of soap also softens and dissolves a part of the cuticle which, when rubbed off, carries with it the dirt. Thus any washing with soap removes the face of the old scarf-skin and leaves a new one. If the hands are too long exposed to the action of an alkaline soap, they become tender, that is, the cuticle dissolves away, and gets so thin as not to protect the inner or sensitive skin. *Wash powders* are inferior to soap, and injure the whiteness

and purity of the skin. If soap produce irritation, it is because the skin is in some way morbid. It should then be used in small quantity at first, increasing it gradually.

800. **Philosophy of washing the Face.**—Dr. Wilson thus pleasantly discourses on the art and mystery of cleansing the face. "And now, dear reader, having determined to wash your face, how will you set about it? there are many wrong ways of effecting so simple a purpose; there is but one right way. I will tell it to you. Fill your basin about two-thirds full with fresh water; dip your face in the water, and then your hands. Soap the hands well, and pass the soaped hands with gentle friction over the whole face. Having performed this part of the operation thoroughly, dip the face in the water a second time, and rinse it completely: you may add very much to the luxury of the latter part of the process by having a second basin ready with fresh water to perform a final rinsing. And now you will say, 'What are the wrong ways of washing the face?' Why, the wrong ways are—using the towel, the sponge or flannel as a means of conveying and applying the soap to the face, and omitting the rinsing at the conclusion. If you reflect, you will see at once that the hands are the softest and the most perfect means of carrying the soap, and employing that amount of friction to the surface with the soap which is necessary to remove the old and dirty scarf, and bring out the new and clean one from below. Moreover, the hand is a sentient rubber, or rubber endowed with mind; it knows when and where to rub hard, where softly, where to bend here or there into the little hollows and crevices where dust is apt to congregate; or where to find little ugly clusters of black-nosed grubs, the which are rubbed out and off, and dissolved by soap and friction. In a word, the hand enables you to combine efficient friction of the skin with complete ablution; whereas in every other way ablution must be imperfect. Then, as regards drying the face, a moderately soft and thick towel should be used; a very rough towel is not desirable, nor one of thin texture. This is a point that may be safely left to your own taste and feelings. The question of friction during the drying is of more consequence, and this is a reason why the towel should be moderately soft, that you may employ friction and regulate the amount. With a very rough towel it is impossible to use friction, for its tenderest pressure may be enough to excoriate the skin; and a very soft towel is equally open to objection from its inadequacy to fulfil the obligation of friction during the process of drying. In washing the face you

have three objects to fulfil—to remove the dirt, to give freshness, and to impart tone and vigor to the skin."

801. **Cleansing the Teeth.**—The effect of talking, singing and breathing through the mouth, is to evaporate the water of the saliva, leaving its solid constituents, animal matter and salts, as a residue which accumulates upon the teeth as *tartar*. This, together with the fragments of the food which get lodged in the cavities between the teeth, is a constant cause of impurity in the mouth, which should, therefore, be often cleansed. Dentifrices are preparations of liquid, paste and powder for cleansing the teeth. Some act chemically to dissolve the tartarous incrustation, as dilute muriatic acid, which also removes discolorations and whitens the teeth. But it also corrodes their enamel, and rapidly destroys them. Its habitual or frequent use is, therefore, most pernicious. It may be rarely and cautiously employed to efface dark spots or black specks upon the teeth, but it should be quickly neutralized with chalk, and washed away with water. Tooth powders, which act mechanically, are better. They require to have a certain degree of hardness or grittiness to enable them to remove the foreign substances adherent to the teeth; but if too hard, they injure the enamel. The powder of ground pumice stone is employed, but it is too sharp for any thing more than exceptional use—say once in two or three months. Chalk is soft and excellent; not common chalk pulverized, for that contains flinty particles, but prepared chalk of the druggist. Charcoal and powdered cuttle fishbone are good tooth detergents. Yet all insoluble powders are liable to the objection, that they accumulate in the space formed by the fold of the gum and the neck of the tooth, presenting a colored circle. The powder is therefore often colored red with *carmine* or *bole armeniac*. *Myrrh*, cinnamon, &c., are added as perfume. *Rhatany*, cinchona, and *catechu*, are added to exert an astringent and hardening effect upon the gums. If substances are required which shall dissolve in using, *sulphate of potash*, *phosphate of soda*, *cream of tartar*, and common salt may be used. Disinfecting and deodorizing tooth-powders and washes which destroy the unpleasant odor of the breath, and tend to whiten stained teeth, owe their efficiency to chloride of lime (807). Such a preparation may be made by mixing one part chloride of lime with twenty or thirty of chalk. A disinfecting mouth-wash is made by digesting three drachms of chloride of lime in two ounces of distilled water, and to the filtered solution adding two ounces of spirit, and scenting, as with attar of roses.—(PEREIRA.)

IV—CLEANSING THE AIR.

802. It was noticed (303) that the atmosphere constantly tends to self-purification; its oxygen is a universal cleanser; it gradually but certainly consumes the noxious gases that are poured into it, from whatever source. Yet its action is slow, and it often happens that injurious exhalations are set free in such quantities, or in such confined spaces, as to require other and active means for their removal. Besides ventilation, other methods are also to some extent available for getting rid of atmospheric impurities, some of which will now be noticed. The subject of malaria, air-poisons, atmospheric infection—what they are, how they act, and in what manner and to what extent they are capable of counteraction—is yet involved in much obscurity. The substances which relieve us of disagreeable odors and noxious emanations are numerous, and take effect in various ways.

803. **Palliatives and Disguisers.**—When atmospheric impurities report themselves to the olfactory sense, they are pretty sure to receive attention, though we too often seek only relief from the disagreeable smell. This is done, not by removing it, but by smothering or overpowering it with sweet scents. With musk, attar of roses, lavender, odoriferous gums, fragrant spices, aromatic vinegars, &c., a cloud of perfume is raised which masks the unwholesome odor. This may be often an excusable resort, but it is too frequently a slovenly expedient to conceal the effects of uncleanliness. "They are the only resources in rude and dirty times against the offensive emanations from decaying animal and vegetable substances, from undrained and untidy dwellings, from unclean clothes, from ill-washed skins and ill-used stomachs. The scented handkerchief in these cases takes the place of the sponge and the shower-bath, the pastile hides the want of ventillation, the attar of roses seems to render the scavenger unnecessary, and a sprinkling of musk sets all other stenches and smells at defiance. The fiercest demand for the luxury of civilized perfumes may exist where the disregard of healthy cleanliness is the greatest." In this connexion we may mention those agencies which exert a palliative effect, *removing* rather than concealing or destroying the offensive bodies. Thus, sulphuretted hydrogen, the gas of rotten eggs, and which is copiously set free from putrefying animal bodies, may be absorbed by water, but the water does not decompose or neutralize it; if heated, it all escapes back again into the air. The moist soil also acts as an absorbent of bad gases, fixing and retaining them during cold and wet weather, and setting them free during drought or heat.

804. **Action of Disinfectants.**—A large number of substances have been discovered which destroy evil odors and injurious gases. These are termed disinfectants, and act chemically either to decompose the noxious substances or to combine with them, producing new and harmless compounds.

805. **Freshly Burned Lime—Quicklime.**—Lime newly burned, caustic and hydrated (slaked), is used to purify the air. It has a powerful attraction for carbonic acid, half a cubic foot of it absorbing nearly 40 cubic feet of the gas. A few lbs. of it placed upon a board or tray in the bed-room, or oftentimes in the sick-room, rapidly absorbs this deleterious substance, while the condensed gas is immediately replaced by an equal volume of fresh air from without. The only inconvenience is, that as the lime combines with the acid, the water used in slaking is set free, which charges the air with aqueous vapor. The inhabitants of newly built houses, and even after a considerable time, often experience a similar annoyance. It is not from the ordinary wetness of new walls that the moisture proceeds, but from the dry hydrate of lime in the mortar. The carbonic acid of the room, from the lungs of its inmates, gradually penetrates the plaster and displaces this water. When quicklime is strewed over fresh animal and vegetable substances, it retards their decay, and so influences the changes that ammonia and other volatile and strong-smelling compounds are less freely produced. If spread upon putrefying refuse, it acts differently, seizing upon the acids and setting free the pungent gaseous alkalies. It at first liberates a large amount of offensive gaseous matter, and then checks the decomposition.

806. **Chlorine as a Disinfectant.**—But the most powerful disinfecting agent is *chlorine gas*, one of the elements of common salt (590). It is an energetic chemical agent, used for the destruction of coloring matters, as in bleaching cotton, linen, fatty substances, &c. The remarkable lightness and tenuity of hydrogen have been referred to (76). It combines with many heavier elements, forming compounds of extreme volatility, lighter than the air, and which constantly ascend into it. It is this highly rarefied gas which seems to stand closest upon the borders of nothing,—but becomes potent through its very nothingness, that gives wing to the deadly exhalations, lifting them away from the ground into the breathing region. The gaseous poisons of the air, so far as known, are compounds of hydrogen. For this substance chlorine has a strong attraction, decomposing and destroying its compounds, and being a gas, it may also diffuse through the air, and thus cleanse and disinfect it.

807. **Forms of its use—Chloride of Lime.**—Chlorine gas may be set fire in two ways: *first*, by pouring hydrochloric acid upon finely powdered black oxide of manganese; and *second*, by pouring sulphuric acid upon a mixture of common salt with the same oxide. Chlorine stands first as a disinfectant. It is cheap, easily prepared, acts efficiently though diluted with much air, and in this state of dilution is breathable without injury even by the sick. It corrodes metallic substances, which should therefore be removed as far as possible from apartments in which it is to be used. (Other disinfecting gases are liable to the same objection.) If it be desired to generate large quantities of chlorine, the methods just mentioned may be resorted to, but apartments cannot then be occupied, as chlorine in any considerable amount is to a high degree irritating and inflammatory to the throat and air passages. In all common cases *chloride of lime* may be employed. This is lime charged with chlorine gas, which combines with it so easily that it is slowly set free when exposed to the air. It has a double action: the lime combines with all acid bodies as carbonic acid, sulphuretted hydrogen, while chlorine diffuses through the air, decomposing all the noxious compounds of hydrogen. It may be spread upon any putrefying substance, when it destroys noxious bodies as they are formed. It may be placed in a room, when carbonic acid slowly combines with the lime, and the chlorine is gradually set free. It may be dissolved in water and sprinkled through bad smelling apartments, or cloths dipped in a diluted solution of it can be hung up in the room. After infectious diseases, a weak solution of chloride of lime should be sprinkled over sheets and family linen before washing, and the walls of the room washed down with it. Chloride of soda is used in the same manner as chloride of lime.

808. **Disinfection by Sulphurous Acid.**—When sulphur is burned in the open air, oxygen combines with it, producing *sulphurous acid gas*. It has a noxious odor, and if largely mingled with the air, is injurious to health. It is an active chemical agent, much used for bleaching, as may be illustrated by holding over a burning sulphur match, a red rose, which is immediately whitened. Woollen, silk, and other garments are bleached by it. It is of a strongly acid nature and combines with alkaline vapors of the air, while it decomposes and destroys other substances, as sulphuretted and phosphuretted hydrogen. When an apartment is fumigated by burning sulphur, it is necessary to leave it; it corrodes metals.

809. **Other Substances used for Disinfection.**—*Chloride of iron* is a

cheap and efficient disinfectant, though it imparts a brown or bluish stain wherever its solution falls. *Chloride of zinc* is equally efficient, but more expensive. *Sulphate of iron* (copperas or green vitriol) has strong disinfecting power. Either of these substances dissolved in water, (one, two, or three lbs. to the pailful,) thrown into vaults, cesspools, or gutters, or over any foul masses of fermenting matter, exert not only a disinfecting and deodorizing action, but partially arrest putrefactive change. *Acetate* and *nitrate of lead* are strong disinfectants. These substances are all solids. They do not assume the gaseous form, but act, dissolved in water, by *fixation* of noxious substances as they are set free.

810. **Effects of Charcoal.**—It is well known that charcoal is a powerful deodorizer. Strewn over heaps of decomposing filth, or the bodies of dead animals, it prevents the escape of effluvia. Tainted meat surrounded with it, becomes sweetened. Foul water strained through it is purified. Placed in shallow trays in apartments where the air is offensive, it quickly restores it to sweetness, and even purges the putrid air of dissecting rooms. Charcoal has also a powerful attraction for coloring substances, and is used for bleaching sirups, liquors, &c., by filtration through it.

811. **Mode of Action of Charcoal.**—Charcoal produces these effects in a particular manner, unlike any substance that has been noticed. Most, if not all porous solids, have the power of absorbing and condensing gases within their minute interior spaces. Charcoal is exceedingly porous, and has this property pre-eminently. A cubic inch of freshly burned, light, wood charcoal, will absorb nearly 100 inches of gaseous ammonia; 50 or 60 of sulphuretted hydrogen, and nearly 10 of oxygen. The charcoals are not all alike in efficacy. Animal charcoal—from charred animal substances—and peat charcoal, are both superior in absorbing and condensing power to wood charcoal. But how does this substance produce its effects? It was formerly supposed, simply by sponging up the deleterious gases and retaining them in its pores. But later inquiries have thrown light upon this matter, and we now understand that by means of this mechanical condensation, charcoal becomes a powerful agent of destructive change. Chemical action is hastened in proportion to the nearness with which the atoms can be brought together. In the pores of the coal they are forced into such close proximity, as rapidly to augment the chemical changes. The condensed oxygen seizes upon the other gases present, producing new compounds, oxidized products. In this way ammonia is changed to nitric acid, and sulphuretted hydrogen to sulphuric acid.

In this way, charcoal promotes oxidation, so that instead of being an antiseptic or preventer of change, it is really an accelerator of decomposition.* This active property of hastening decomposition has been made medically available in the form of poultice, to corrode away sloughing and gangrenous flesh in malignant wounds and sores. Dr. BIRD, in his work on the medical uses of charcoal, quotes several cases: we give one. "A man was admitted to St. Mary's hospital with a sloughing sore upon his leg. A poultice of this kind was put on, and in six hours the dead portion was reduced in size fully one-quarter. At the same time, the poultice thus made, effectually prevents any odor or putrefying exhalations proceeding from the slough and pervading the apartment." Dr. STENHOUSE, who, in 1855, first drew distinct attention to the fact, that charcoal is rather a hastener of decomposition than an antiseptic, has contrived ventilating arrangements in which the air of dwellings is filtered through charcoal. He has also a breath-filter or respirator, consisting of a hollow case of fine flexible wire-gauze, which is mounted upon the face, as shown in Fig. 130. It is filled with coarsely powdered charcoal, so that all the air that enters the lungs is strained of its impurities. Charcoal is thus strongly commended as a disinfectant. It has many advantages over the preparations of chlorine, as it neither injures the texture of substances, nor corrodes metals, nor discharges the color of fabrics by contact, nor gives off disagreeable fumes. It is never in any application or use, poisonous or dangerous, but is entirely innocent, and in only one solitary instance can it become pernicious, and that is when it ceases to become charcoal, and is burnt in a perfectly closed room.

FIG. 130.

* "I took the body of an English terrier, weight about ten lbs., placed it on a stone floor in a small apartment, and lightly covered it with charcoal; although the weather was very warm, not the slightest odor could be detected. By some accident the charcoal was disturbed, and a large portion of the mass was left uncovered; in spite of this the circumjacent charcoal was sufficient to prevent any offensive stench. Upon seeing this, I left the body completely uncovered, merely surrounding it with the deodorizing agent; this again prevented any disagreeable smell. Having determined this fact, I again covered the carcass. In less than a fortnight not a particle of flesh remained upon the bones, which were picked perfectly clean, and were of a snowy whiteness."—(BIRD ON CHARCOAL.)

V.—POISONS.

812. **Poisons and Poisoning.**—Poisons are divided into three classes according to the way they act upon the system. *Acrid* or *irritant* poisons directly corrode or destroy the tissues with which they come in contact, and cause intense pain, but do not suspend consciousness. Strong acids, and alkalies, and indeed all poisonous metallic substances, belong to this class. *Narcotic* poisons are such as produce stupor, as opium, carbonic acid. *Narcoto-acrids*, as tobacco, alcohol, &c., act both as acrids and narcotics. Some of these poisons may be arrested or neutralized in the system before producing fatal results, if measures are promptly taken, but no time is to be lost. Whatever is done, must be done at once; the delay necessary to ransack books for antidotes, or to get a physician, may cost the victim's life. If severe pain in the stomach, vomiting, purging, &c., come on after a meal, poisoning is to be suspected. Something may be gathered from the demeanor of the poisoned individual, and a knowledge of circumstances. A person who has swallowed poison, by way of suicide, will be apt to be more silent about it than one who has taken it accidentally or to whom it has been administered purposely.

813. **Resources in case of Poisoning.**—If the vial or vessel from which the poison was taken be accessible, or if there be discolored spots upon the dress, and if on applying the tongue to either there is *sourness*, we infer that the poison is acid. In this case, or if it be known that an acid has been swallowed, chalk or whiting, mixed with milk, should be given copiously. If these are not at hand, plaster torn from the wall, or soap, may be substituted. Alkalies are given as antidotes to acids, and the reverse. Thus, poisoning by oxalic or sulphuric acids may be remedied by soda or saleratus, while poisoning by pearlash would be arrested by vinegar. So if lime get into the eyes, it may be dissolved and washed out by moderately strong vinegar. The antidote for corrosive sublimate is eggs; for sugar of lead, epsom salts. If other or unknown poisons have been taken, the stomach should be freed of its contents as speedily as possible by an emetic, the readiest and best being a teaspoonful of mustard stirred up with warm water, its action being promoted by copious draughts of the latter. The poison called *arsenic* or *ratsbane* is not the *metal* arsenic, but the oxide of arsenic—a white, slightly sweetish insoluble powder. Being destitute of any decided taste, it is eminently fitted for the purpose of the poisoner, as it may be mingled with food without easy detection. But while this circumstance is fitted to tempt the mur-

derer, there follows another which is fraught with sure retribution No poison is so ready and certain of detection as arsenic. And not only this, but "it is as indestructible as adamant. The corpse may decay; the coffin fall to dust; hundreds or thousands of years may pass, but underneath the mound of earth, in the spot where the corpse was laid, there is the arsenic." The best antidote to this poison is the hydrated sesquioxide of iron, which combines with it, forming an inert compound; in the absence of this, milk, sugar, eggs, &c., may be given, and an emetic should be administered as quickly as possible to relieve the stomach of its contents: it must be prompt to be available.

APPENDIX.

A.

ADDITIONAL LIST OF TEMPERATURES.

Lowest artificial cold 187° below zero, or 219° below freezing water
Carbonic acid freezes 148° below zero, or 180° below freezing water.
Lowest natural temperature at Yakutsk, in Siberia, 84° below zero.
Estimated mean temperature of the North Pole, 13° below zero.

Salt water of specific gravity 1·104, and oil of turpentine freezes,	14°
Wine freezes,	20°
Blood freezes,	25°
Milk freezes,	30°
Water freezes,	32°
Alcohol boils in a vacuum,	36°
Mean winter temperature of England,	37.8°
Temperature of hybernating animals,	38°
Mean winter temperature at Rome,	41°
Mean annual temperature at Toronto,	43°
Putrefaction begins,	50°
Cultivation of the vine begins at a mean annual temperature of,	50°
Mean annual temperature of New York,	54°
Mean annual temperature at Rome,	59°
Cultivation of the vine ends,	65°
Water boils in a vacuum,	72°
Temperature of glow-worm and cricket,	74°
Silk-worm hatches—temperature of germination,	77°
Tepid bath begins,	86°
Acetous fermentation,	89°
Putrefaction rapid,	93°
Tepid bath ends,—warm bath begins,	95°
Temperature in man—blood heat,	98°
Warm bath ends,—vapor bath begins,	99°
Cold-blooded animals die,	106°
Vapor bath ends,	130°
Temperature in a boat in Upper Egypt,	138°
Steamboat's engine-room (West Indies),	155°
Starch converted to sugar,	160°
Finland vapor bath,	170°
Alcohol (specific gravity ·794) boils,	174°
Water boils at the summit of Mont Blanc (15,360 ft. elevation),	182°
Water boils at an elevation of a mile,	202°
Water boils at the sea-level,	212°

Syrup, 52 per cent. sugar, boils,	216°
Water of the Dead Sea boils,	223°
Syrup, 80 per cent. sugar, boils,	264°
Gypsum converted to plaster,	291°

B.

We append an illustration of the astonishing scale of minuteness upon which even *art* has found it practicable to conduct her operations. Within a circle of but one-thirtieth of an inch in diameter—a mere visible dot, as we see in the figure, M. Froment, by an exquisite mechanical contrivance, executed an elaborate piece of writing and engraving. Of course no result was visible to the naked eye; but when the work was placed under a compound microscope, its details came out, as we see in fig. 131, which is a transcript of the magnified view. With what marvellous accuracy were those *infinitesimal* movements performed.

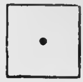


Fig. 131.

QUESTIONS.

PART I.—HEAT.

Page 17.—I. SOURCES AND DISTRIBUTION OF TERRESTRIAL HEAT.

1. What is heat? What of its essence or nature? What is stated of its importance? 2. How much heat does the earth receive from the sun annually? How do we ascertain the total amount of heat thrown off from the sun, and how much is it? 3. Is there any loss of solar heat? What may reasonably be inferred about the celestial movements of heat? What are the results of *Poulet's* researches? 4. Why are unequal quantities of heat received from the sun at different places? What examples are given of the unequal diffusion of heat?

Page 19.—II. INFLUENCE OF HEAT UPON THE LIVING WORLD.

5. What controls the distribution of plants upon the earth? How do we see this exemplified? 6. In passing from the equator to the arctic regions, what do we observe in relation to animals? Why is this? Are all animals equally subject to this influence? 7. Does temperature affect man also? How in the polar regions? How in the tropics? 8. How does the dress of the West Indian contrast with that of the Greenlander? What does Dr. Kane observe on this subject? 9. What is the effect of cold and warmth upon the animal body? What controls the intensity of the action of external nature upon the senses? What is the character of the people in cold countries? In hot? In temperate? What is said concerning the appearance of great men upon the earth? 10. How may the scarcity of fuel affect national character? To what may the polished manners of the Parisians be referred? 11. What has been suggested concerning the relation of climate to language? 12. In the absence of a natural defence from heat and cold, how does man shield himself? What is said of the art of producing artificial climate?

Page 23.—III. MEASUREMENT OF HEAT.

13. What is meant by the equilibrium of heat? Give an example. 14. What condition must precede the tendency of heat to an equilibrium? How are we enabled to become acquainted with it? 15. How does heat affect the bulk of bodies? Mention some familiar examples. 16. What is said of the expansion of different substances by heat? What forms of matter expand least? What most? Why is heat said to be imponderable? 17. What is the principle of the thermometer? What is the freezing point? Boiling point? What are degrees? 18. How is the scale of the common thermometer obtained? How does it differ from the centigrade scale? From Reaumer's? 19. What does the word thermometer mean? What mistake must we avoid? What does it actually show us? 20. Why should the thermometer be in constant use in the family? 21. What points of temperature are given in the table?

PAGE 27.—IV. RADIATION OF HEAT.

22. What is radiant heat? Are all bodies radiators? Give an example. 23. Is the decrease in the force of heat as you recede from its source the same in all cases? What is the rate of decrease as you pass from a radiant point? Is it different with a surface? 24. What is said of the transparency of bodies to light and heat? How do solar and artificial light differ? Mention the degree of transparency of various substances compared with air? 25. To what is the heating power proportional? Why is not the air warmed by the direct rays of the sun? 26. When do bodies part with their heat most rapidly? What other circumstance affects radiation, and how? What are the best radiators? The worst? Give examples. How may the radiating power of a metallic surface be increased? Describe Rumford's experiment. 27. How does Dr. Lardner explain the action of polished surfaces? 28. What vessels are best to keep their contents warm? What is said of tea-kettles, and pipes and stoves for warming rooms? 29. What is said of the effect of color? 30. What is reflected heat? Why cannot a good reflector be warmed? How does the absorbing compare with the reflecting power in glass? How in polished silver? What is the difference between radiant and reflected heat? 31. Does color influence absorption? Describe Franklin's experiment. What is the effect of a dark soil? Dark walls for grapes? Dark clothing? 32. Do all bodies radiate heat? Explain Fig. 5. 33. Why are starlight nights colder than cloudy ones? 34. What were the old ideas of the cause of dew? How does Dr. Wells explain it? What common phenomena are explained in the same way? What is meant by dew-point? 35. Why is dew more copious on some bodies than others? Why is there no dew on windy nights? What relation is there between cold nights and heavy dews? 36. Why is there no dew under trees? On cloudy nights? In valleys? 37. What is frost? What precautions may be taken to prevent injury from frost?

PAGE 34.—V. CONDUCTION OF HEAT.

38. Explain Fig. 6. 39. What is said of the different conducting power of different substances? What bodies are the best conductors? What are the worst? 40. What is Rumford's table? 41. How has nature protected the earth and animals from excessive cold? What advantage have non-conducting materials in the walls of houses? What is the comparative conducting power of the leading building materials? 42. What is the difference in conducting power between moist and dry air? Why are saw-dust, tan-bark, &c., good non-conductors? What is said of double windows? Why is not air used instead of porous materials to enclose ice-houses? 43. What is said of the conducting power of the materials of our clothing? 44. Why are we unable to know how hot a body is, by touching it? How is this shown by experiment? Why can we endure a higher temperature in air than water?

PAGE 36.—VI. HEAT CONVEYED BY MOVING MATTER.

45. What is said of the conducting power of water? How is this shown? What is convection of heat? 46. Explain Fig. 8. What causes the currents?

PAGE 37.—VII. VARIOUS PROPERTIES AND EFFECTS OF HEAT.

47. How does heat affect the form of bodies? 48. What is the relation of heat to liquidity? Give examples. What is said of the freezing of water? What is meant by caloric of fluidity? Caloric of elasticity? 49. What is specific heat? What substance has the greatest specific heat? How does it compare with others? 50. Why is water made to hold a large amount of heat? 51. Why is it so cooling when drank? 52. What relation is there in regard to the densities of bodies and the heat they contain? How is this accounted for? Explain the fire syringe. 53. What is latent heat? How is the latent heat of melting ice ascertained? 54. What is said of the beneficial effects of this law? 55. Does heat always become latent when solids change to liquids? How are artificial freez-

ing mixtures produced? 56. How does the freezing of water affect the temperature? How may this principle be applied? 57. What is evaporation? When is it most rapid? 58. Describe the boiling process? 59. How can the nature of the vessel affect the boiling point of a liquid? 60. Explain the principle and the construction of the barometer. Why does the mercury sink in going up a mountain? 61. Why cannot meat be well boiled on a high mountain? 62. Why is air removed from the boilers in sugar refining? 63. How may the boiling point of water be elevated? 64. What causes the dancing of the drop of water upon a hot stove? What temperature of surface is required to produce the spheroidal state in water? 65. Why may the fire be reduced when the water has begun to boil? 66. What is the plan of Hecker's farina-kettle? 67. Why do puddings, &c. cool more slowly than water? 68. What is the latent heat of steam? How is it ascertained? 69. Why are damp soils cold? What is the effect of evaporation in hot climates? From the skin and lungs? How does fanning the face cool it? 70. Why are we more subject to take cold when sitting by a crack or hole? Explain blowing hot, and blowing cold.

PAGE 48.—VIII. PHYSIOLOGICAL EFFECTS OF HEAT.

71. How is the sensation of warmth produced? What is the effect of still increasing the degree of heat? 72. What is said of heat as a stimulant? How do tropical diseases illustrate this? 73. What is said of the effect produced upon the system by sudden changes of temperature? What is the best degree of warmth in apartments?

PAGE 49.—IX. ARTIFICIAL HEAT—PROPERTIES OF FUEL.

74. What is the source of all the heat employed for household purposes? What are the main elements of the air, and their relative proportions? What are the properties of nitrogen? Of oxygen? 75. What is the chemical composition of fuel? How does the proportion of oxygen affect the value of fuel? What is said of carbon? 76. What are the properties of hydrogen? How does it exist in fuel? Explain the origin of flame. 77. What is said about the properties of fuel, in relation to kindling a fire? 78. What are the two leading circumstances in burning fuel? What becomes of the fuel? What is said of carbonic acid? 79. How is fuel changed before it is burned? In what does burning consist? 80. Upon what does the heat developed by fuel depend? Why does hydrogen give out more heat in burning than carbon? 81. How much water does wood contain? What kinds of wood contain most? How much in air-dried wood? How does the presence of water injure wood for fuel? Example? 82. Why is wood sold by measure, instead of weight? What wood has the greatest heating value? What the least? 83. What circumstances of growth favor the formation of hard wood? 84. Which gives most flame, hard or soft wood? Which the most hot coals? Why is this? When is it best to burn soft wood? Why? 85. How does new differ from old charcoal in composition and in burning? 86. What is the origin of mineral coal? Why must other fuel be used to kindle it? What is said of the burning of anthracite? 87. What is bituminous coal? How does it burn? Fat coal? Coke? What are its qualities? Why is it preferred to anthracite? 88. What is lignite? 89. How do these fuels compare in heating power? 90. How much air is required to burn a pound of charcoal? Of mineral coal? 91. What is said of excess of air in combustion?

PAGE 55.—X. AIR CURRENTS—ACTION AND MANAGEMENT OF CHIMNEYS.

92. Why does the candle flame tend upward? Explain the draught in chimneys. 93. Why has a tall chimney a stronger draught than a short one? What conditions insure a violent draught? Within what limits must these conditions be restricted? Why? 94. When and how does wind cause chimneys to smoke? How may it be prevented? 95. Why do new chimneys sometimes smoke? 96. What trouble often occurs from chimneys on the cold side of a house? 97. How may it be shown that air currents are very easily established? Why cannot the current from a fire traverse two flues at a time?

98. How may one chimney overpower another? Is there any remedy for such a state of things? 99. How should flues entering chimneys be arranged? What is the effect of kindling a fire in an upper room, when there is none below? In the lower room, when there is none above? How is this difficulty obviated? 100. What results are apt to flow from large openings in fireplaces? How should the throat be constructed? 101. What is the most common cause of smoky chimneys? How are double currents in chimneys caused? What was Dr. Franklin's plan for remedying this difficulty? 102. What is said of currents in a room affecting the chimney draught? 103. What is smoke? How is its weight shown? What is said of the falling of smoke in bad weather? What of watery vapor in smoke? 104. How does smoke vary in composition?

Page 60.—XI. APPARATUS OF WARMING.

105. Why are the effects of heating on the air of rooms not mentioned here? 106. How do rooms lose their heat? How may much of the loss by windows be prevented? 107. How do our bodies warm a room? Describe the experiment. How does a crowd affect the air? 108. Before the time of chimneys, how were rooms warmed? 109. Describe the first fireplace. How have they been improved? What is said of the jambs? 110. How does the open fireplace warm the room? What becomes of the heated air? How are the different parts of the room heated? 111. In what two ways does fuel give out heat? Why is the open fireplace so wasteful of heat? How much heat is lost in those best constructed? By what means may it be improved in economy? 112. Describe the Franklin stove. What are its advantages? 113. Why will a smaller fireplace do for coal? Why is the coal-grate more economical than the fireplace? How should it be made? 114. What considerations determine the form of the front? In what does the art of burning fuel in grates consist? What is said of the depth of fuel in the grate? 115. What is said of the different kinds of grate? Describe Golson's. Franklin's. 116. Describe Dr. Arnott's grate, and the mode of using it. What is said of the idea of burning smoke? What should be the aim? 117. What is the objection to placing grates very low? Explain Fig. 18. 118. How do stoves communicate their heat? 119. What is said of different materials used for making stoves? 120. What is the principle of the self-regulating stove? Describe it. 121. Why is the air-tight stove not economical? What was the result of Dr. Ure's experiments? What is the most economical mode of getting heat from fuel? 122. How is the heated current from the stove affected in passing through the pipe? How do elbow joints act? Why is little gained by extending the pipes greatly? 123. What are the most desirable qualities in a stove? 124. What is the plan of the hot-air furnace?. What is said for and against these furnaces? 125. What are the disadvantages of sending streams of hot air into a room through a register? Where will the coldest part of the room be found? How has the air been found to arrange itself in heated rooms? 126. Why are we not readily warmed by hot air? How is it shown that hot air may be made a source of cold? 127. How is the principle of the hot water apparatus illustrated? How is water adapted for heating? 128. What are the two methods of heating by hot water? How do the results obtained from them differ? 129. Describe the construction of the steam apparatus. What is said of its action? 130. How are these methods of warming in respect of danger from fire? 131. What is said of the origin of fires in London? 132. Give the chief advantages and disadvantages of heating by the fireplace. The stove. The hot-air furnace. The hot water apparatus.

PART II.—LIGHT.

Page 76.—I. NATURE OF LIGHT.

132. What is said of the means by which we gain a knowledge of the outward world? 133. How do light and darkness affect the mind? How is this illustrated? 134. What was the ancient idea of light? 135. What was the first scientific explanation of light?

What view of light is now generally accepted? 136. At what rate does the intensity of light diminish, from the point of emission? What circumstance modifies the result? 137. In what different ways do bodies receive the light that falls upon them?

PAGE 79.—II. REFLECTION OF LIGHT.

138. What is reflection of light? 139. How is a perpendicular ray reflected? An oblique ray? How may this be shown? 140. Explain Fig. 23. Fig. 24. 141. What is it that reflects the light in looking-glasses? How is the image formed? Why does it appear behind the glass? How does the form of the reflecting surface affect the image? 142. What would be the effect of perfect polish in a surface? 143. What is irregular reflection? Why can a sheet of white paper be seen where a mirror cannot? How do objects become visible, in the absence of an original fountain of light? 144. How should pictures be managed in respect to reflection? Why are they inclined forward when hung high? How should the light fall upon a picture? 145. What is said of the effect of the atmosphere on light?

PAGE 82.—III. TRANSMISSION OF LIGHT.

146. What is said of perfect opacity? Of perfect transparency? What depth of air would absorb all the sun's light? Of water? 147. Explain refraction of light. Why do window panes produce no distortion? When light passes from one medium to another, how is it affected? 148. Explain Fig. 29. What is meant by index of refraction? 149. What are lenses? How do the different lenses change the direction of light?

PAGE 84.—IV. THEORY OF LIGHT—WAVE-MOVEMENTS.

150. What is light? 151. What examples are given of visible wave-motions in nature? 152. How is sound communicated? How is it shown to be vibratory motion? 153. What causes difference of pitch in sounds? Describe Savart's machine. 154. What results were obtained in reference to the musical scale? How is a unison produced? A concord? A discord? 155. What is assumed in the wave-theory of light? What is meant by wave-length? How do the wave-lengths differ in the different colors? 156. How is the number of pulsations of the retina in a second determined? What is said of the credibility of these statements?

PAGE 88.—V. COMPOSITION AND INFLUENCE OF COLOR.

157. How is the solar spectrum produced? What is it composed of? Explain Fig. 35. 158. How does Newton explain colored surfaces? 159. What is Brewster's view of the composition of colors? Explain Fig. 36. Fig. 37. 160. What are complementary colors? How are they shown by the figures? 161. What are tones of color? Shades? Tints? What is a scale of colors? 162. What are hues? 163. Explain the chromatic circle. In what two ways are colors seen to be modified? 164. How may any one easily make such a chart with the real colors? 165. How are complementaries found upon the chart? 166. What is meant by complementary contrast? 167. What are luminous colors? Sombre? Medium? 168. What are grays? Browns? Pure colors? Broken colors? 169. What is said of finding pure colors in practice? 170. What is said of a purchaser looking at colored cloths? How may this be verified? What are the two kinds of result seen? 171. What are colors? What do we mean by the expressions, 'snow is white,' 'blood is red'? From this view, what might we expect? 172. What is said of the duration of impressions upon the retina? 173. What is the effect of gazing at a color for some time? How is this easily shown? 174. What is said of the simultaneous influence of colors upon each other? How is it explained? 175. What is the effect of placing violet beside green? Beside orange? Beside blue? What is the law of the mutual influence of colors? What is the effect of placing violet by the yellow scale? 176. Explain Fig. 45. How is this result accounted for? 177. What does good taste dictate in combining colors? What are the finest combinations? How are harmonies of analogy

produced? 178. What circumstances may disturb the mutual action of colors? 179 How are colors affected by associating them with white? Is the white changed? 180. What is said of associating colors with black? With gray?

PAGE 102.—VI. PRACTICAL SUGGESTIONS IN COMBINING COLORS.

VI. 181. How are these principles applied to dress? 182. Describe the complexion of the blonde? Of the brunette? What colors suit the blonde, and why? What the brunette? 183. What is said of the arrangement of flowers in a bouquet? 184. Why are dark paperhangings bad? What is the objection to red and violet? To orange and yellow? What colors are recommended? What is said of the border? 185. What suggestions are given concerning picture frames? Why are black frames objected to? What should be the ground for gilding? 186. What is said of dark colored furniture? Of red? Of selecting chairs and hangings? Of trimming chairs and sofas? Of the carpet?

PAGE 105.—VII. PRODUCTION OF ARTIFICIAL LIGHT.

VII. 187. What are the sources of natural light? Of artificial light? 188. Describe Dr. Draper's experiment showing the relation between light and temperature? 189. How is all our illumination produced? What processes must all substances used in lighting undergo? 190. What elements are employed in illumination? Which burns first? What happens to the carbon? 191. How may these facts be shown? 192. What is said of the laws of illumination? What is the office of oxygen in this process? Why is a solid necessary? Why must these elements be burned successively? 193. In what three forms are illuminating substances used? 194. From what are candles made? What kinds of tallow are best? How should they be kept? 195. What is the composition of the fats and oils? What are the properties of stearin candles? 196. What is said of spermaceti candles? Of wax? 197. What is the use of the candlewick? How is the burning carried on? 198. How is the flame shown to be hollow? What is contained in the dark space? What causes the odor of a candle just blown out? 199. How is the necessity for snuffing shown? What of plaited wicks? 200. Why cannot the wick of a tallow candle be slender? 201. How are liquids burned? Why are large wicks in lamps apt to smoke? Describe the Argand burner? What are its advantages? 202. What is Lange's improvement upon this lamp? Describe Fig. 51. What is the point to be considered in managing such lamps? 203. How should the reservoir be constructed? How is it in the Astral and Sinumbra lamps? In the Carcel lamp? 204. What is one great difficulty in using lamps? What was Dr. Ure's experiments? How has this difficulty been met? 205. What oils are chiefly used in lamps? 206. What is camphene? What are its properties? 207. Why must peculiar lamps be used to burn oil of turpentine? What is said of the light from camphene? Why is its flame more luminous than that of oil? 208. Why must it be used fresh? 209. What is burning fluid? What is said of this substance? 210. What properties of this substance lead to explosions? 211. How are most accidents with it occasioned? What causes the irregularity of the flame? How are the lamps made safe? 212. Describe Newell's lamp. 213. What is Kerosene oil? What are its advantages? 214. What is said of Sylvic oil? 215. What is said of the consumption of gas? 216. What is it chiefly made from? 217. What are the products of the distillation of coal? 218. How is the gas purified? 219. What is its composition? Why cannot these gases be burned separately? How does the gas differ as the process of distillation goes forward? 220. How is gas made from oil? From resin? How does it compare with coal gas in expense? 221. Explain the gas meter. What does it indicate? 222. Describe the process of burning the gas. What if there is too little or too much air? 223. Does the length of the flame make a difference in the light? 224. What objections are urged against the use of gas? How do the constituents of gas differ in this respect? 225. When gas is so cheap, why is there no saving in its use? 226. How do the tubes become obstructed? What causes the jumping of the flame? 227. In what way can light be measured? 228. Describe the photometer, Fig. 54. 229. Why have

we reached no practical advantages from this? What has been proposed? 230. Give the results of the experiments of Ure. Of Kent.

PAGE 126.—VIII. STRUCTURE AND OPTICAL POWERS OF THE EYE.

231. What is said of the eye? Why is it treated of here? 232. Describe the coats of the eye. 233. What is the pupil? Describe the iris and its action. 234. What is the crystalline lens? The vitreous humor? 235. What is the choroid coat? The *pigmentum nigrum?* 236. How is the optic nerve surrounded? What is the retina? Jacob's membrane? 237. How is vision produced? Where is the image formed? What is said of the touch of the retina? 238. What is the size of the image of the full moon upon the retina? Of a man 70 inches high at 40 feet distance? 239. What is the difference in intensity between sunlight and moonlight? Between sunlight and that of Sirius? 240. When should we avoid using the eyes? 241. Why is novel reading worse for the eye than grave subjects? What other suggestions are made concerning reading habits?

PAGE 131.—IX. OPTICAL DEFECTS OF VISION. SPECTACLES.

242. In perfect vision where is the image? What would follow if the eye were rigid? What is the limit of perfect vision? 243. What causes far-sightedness? Where is the image formed? Why? Why do the far-sighted never see minute objects well? How do they often manage to see them? 244. What is the remedy? How do they act? 245. What directions are given for managing far-sighted eyes? 246. Describe the near-sighted eye. Why can short-sighted people see with a weak light? How may near-sightedness be produced? How should the young, if near-sighted, manage their eyes to correct the difficulty? 247. How do concave glasses act? What directions are given for their selection? What is nervous near-sightedness? What is cataract? 248. How should spectacle glasses always be mounted? Why do persons wearing spectacles turn the head instead of the eye? Where is the clearest vision through glasses? Hence what follows? What are pebble glasses?

PAGE 137.—X. INJURIOUS ACTION OF ARTIFICIAL LIGHT.

249. How does artificial differ from daylight in composition? 250. How may this be shown? 251. Give a list of the substances used in illumination in the order of the purity of light yielded by them. 252. How are colors affected by artificial light? 253. What was Dr. Hooker's experiment? 254. How are these effects explained? 255. What injurious result may follow such use of the eyes? 256. How have the colors of the spectrum been characterized? How may this be explained? 257. What is said of the distribution of heat through the spectrum? Why is artificial light more heating to the eyes than sunlight? 258. Why do we use more of impure light than any other? 259. What is said of the carbonic acid produced by artificial light? 260. What is the objection to an unsteady light? Why are the variations of a strong light less injurious? How does reading in railroad cars affect the eyes? 261. Why do we not see the moon in the day time? How does this apply to our use of artificial light? How can we prove that protecting the eye makes objects more distinct? 262. What does Dr. Hooker remark on this point? 263. Describe the symptoms that bad light produces in the eyes. 264. When the disease is on the nerve, what are the symptoms? 265. If these continue, what others are liable to follow? 266. What is amaurosis? What is said of it? 267. Who are most subject to it?

PAGE 146.—XI. MANAGEMENT OF ARTIFICIAL LIGHT.

268. How do ground glass shades affect the light? 269. When should reflectors be used? 270. What is said of blue shades? 271. How may these be made? 272. How should they be colored? 273. What is said of a blue glass chimney? Of the use of the water globe? 274. Why are colored glasses in spectacles objectionable? 275. Is gas-light necessarily injurious? In what way is it doing much mischief?

PART III.—AIR.

PAGE 150.—I. PROPERTIES AND COMPOSITION OF THE ATMOSPHERE.

276. What considerations lead us to regard the air with amazement? What view gives it a still deeper interest? 277. Why do we not think of the air as a reality? What is said of its weight? How does its pressure vary? 278. What is the weight of a cubic foot of air? How many feet are in a pound? How large a room contains a ton? 279. How do the variations in atmospheric density affect our bodies? How our minds? Why are inhabitants of low, marshy places much affected by a light atmosphere? 280. Why must we study the chemical properties of air? What is its composition? Explain Fig. 68. 281. How do these gases arrange themselves? What is said of this provision?

PAGE 154.—II. EFFECTS OF THE CONSTITUENTS OF AIR.

282. What are the properties of Nitrogen in the air? 283. What is the office of oxygen? How does it get access to all parts of our bodies? 284. What is its purpose in our bodies? What does it accomplish in the brain? 285. If the proportions of this gas are increased or diminished what follows? 286. How much moisture does the air contain at different temperatures? How is the increased capacity for moisture as the temperature ascends, shown? 287. What is the effect of cooling saturated air? How is its drying power determined? Where should the openings be in laundries? Why? 288. When is the dew-point said to be high? When low? How is it found? What is Mason's hygrometer? What results of observations in different places are given? 289. What is said of moisture on windows? Of double windows? 290. How does humidity vary with seasons, climate, hour of the day, &c. 291. What provision is made for the removal of moisture from the body? How much is given off in a day? How is this process affected by damp air? What bad consequences follow? Describe the sirocco. 292. How does dry air affect the system? If very dry, how? What is the Harmattan? 293. What are the sources of carbonic acid in the air? What are its effects when breathed pure? When mixed with air in small quantities? 294. What per cent. of carbonic acid renders the air dangerous to breathe? What is the effect of retaining it in the body? What state of the air does this? 295. Why is it found in the air at all? 296. What follows if we breathe any of the elements of the air separately? What is said of their combined action? 297. What is Alotropism? What is Ozone? What are its effects? 298. What is the common idea about electricity? How is electricity developed in the air? When does the air contain most of it? What do we know on the subject?

PAGE 165.—III. CONDITIONS OF AIR PROVIDED BY NATURE.

299. What becomes of the carbonic acid thrown into the air by respiration? What other impurities does the air contain? What is said of their minuteness? 300. Why should not the dwelling be situated low? What is the effect of dense foliage? What is the best soil around a dwelling? 301. Why is night air unwholesome? 302. How may the air differ in the different stories of the house? 303. How does the atmosphere maintain its purity? 304. Do these remarks apply to air within doors?

PAGE 168.—IV. SOURCES OF IMPURE AIR IN DWELLINGS.

305. What is the effect of breathing and combustion upon the air of rooms? 306. What is said of the leakage of air-tight stoves? How is it with all stoves and furnaces? 307. How do very hot stoves affect the air? How is this explained? 308. What advantage have grates and fireplaces over stoves? What is the consequence of heating the air? Upon what does the dryness of the air depend? Explain Fig. 71. How does parched air affect the body? How can this difficulty with stoves and furnaces be obviated? 309. What common error is mentioned? What is the true statement? What is the state of the air from the ventilator of a crowded room? 310. What is Dr. Faraday's

testimony on this point? 311. What is the condition of the air in an unventilated bed room where two have slept in it? Why are its occupants unaware of it? When the air of inhabited rooms is not changed, what do we see? 312. What is said of man alone being responsible for breathing foul air? 313. What other sources of impurity in houses are mentioned? 314. What colors on paper hangings are poisonous? 315. When are cellars sources of bad air? Why should they be ventilated?

PAGE 174.—V. MORBID AND FATAL EFFECTS OF IMPURE AIR.

316. Why are we more exposed to injury from bad air than bad food? Why is thought required to guard us from its effects? 317. How does breathing bad air load the blood with impurities? What consequences does this prepare for? 318. What were the circumstances of the cholera outbreak in Taunton workhouse, and what do they indicate? 319. What relation has been thought to exist between the kind of impurity breathed, and the disease induced? What may occur to modify the symptoms? 320. What is said of the causes that produce scrofula? 321. How may impure air bring on consumption? 322. What is said of ventilation in regard to infant mortality? What feeling seems to prevail among mothers? 323. What is said of the undermining action of bad air upon the health? 324. Why must the mind suffer at once from bad air? How is it affected?

PAGE 181.—VI. RATE OF CONTAMINATION WITHIN DOORS.

325. How is the amount of oxygen consumed by one person in an hour estimated? Why do the estimates of different persons vary? 326. How does the carbonic acid exhaled correspond in volume with the oxygen inhaled? To what extent does one person vitiate the air in an hour? 327. Why is it difficult to estimate the amount of oxygen withdrawn by combustion? How does the combustion of fuel differ from breathing in its effects upon the air? 328. How rapidly do candles contaminate the air? Oil lamps? Coal gas? 329. What relation exists between the dew-point of the air and our bodily comfort? What estimates are given? 330. How much air is vitiated by one person in a minute? What is said of the economical aspect of this subject? 331. What estimates are given of the effects produced upon the air by a certain number of persons in a room of given size? How is it in actual practice? What is said of size of apartments in this relation? 332. How do plants affect the air of rooms?

PAGE 185.—VII. AIR IN MOTION—CURRENTS—DRAUGHTS.

333. By what two methods may the air be purified? 334. How is ventilation effected on a large scale? What force is employed in private residences? 335. Explain Fig. 72. Fig. 73. If several lights are in the room, what follows? 336. What is said of the action of the body in producing currents? 337. Explain how it is that tight windows produce currents. What caution is given? How is it in summer? 338. What causes the air to arrange itself in layers? How are the impurities distributed? Will the action of windows and fireplace prevent this? What is said of sleeping on the floor? 339. Explain Figs. 75 and 76, showing that simple openings do not produce currents. 340. When the conditions are changed, as in Figs. 77 and 78, what happens? Why should there be two openings? 341. Explain Fig. 79. Fig. 80. 342. When will an open door or window empty the room of its air, and when not? What is said of the laws which govern the motion of air? 343. How does exposure to air-currents affect the system? What is said of the velocity of currents? Why is it important to be exposed to them?

PAGE 192.—VIII. ARRANGEMENTS FOR VENTILATION.

344. Why cannot a fire be kindled in a tight room? Why were the early fireplaces better than the modern ones for ventilation? Why was the settle used? How are the upper portions of the room affected? How does the double fireplace act? 345. How do stoves rank as a means of ventilation? How can they be made to a'd in ventilation?

346. What is said of ventilation by hot-air arrangements? Why is a flue necessary What is the great danger in this mode of ventilation? 347. How much moisture wil air heated from freezing to 90° require? How is moisture supplied to the air of the House of Commons? What is said of the usual supply? What is recommended? 348 How do the fireplace and air-heating apparatus act in combination? Why cannot this method become common? 349. How does bad carpentry influence the progress of the art of ventilation? 350. What four points should ventilation secure? What is the real state of things in these respects? 351. For what are milinet and wirecloth doors recommended? What is said of lowering the top sash in winter? of louvres and other contrivances? Where should the air brought into rooms come from? What is Emerson's Ejector? What methods of admitting air are mentioned? 352. Describe Lyman's Ventilator. 353. What considerations naturally lead us to make openings in the upper portions of our apartments? 354. What is the practical difficulty with these openings? How may this be avoided? 355. What, after all, must be the main reliance? What difficulty is Arnott's valve designed to obviate? How does it do it? 356. What is said of its value? 357. What use are chimneys in summer? 358. What is said of the action of additional flues for ventilation? 359. Why do the bedrooms require special care? How do we generally find them? What can be done? 360. How may gas-light be ventilated? 361. How may cellars be ventilated? 362. What is the present state of the art of ventilation? Why is it little surprising that it should be so? 363. What is the main obstacle to ventilation? Why is it bad economy to neglect it?

PART IV.—ALIMENT.

PAGE 205.—I. SOURCE OF ALIMENTS—ORDER OF THE SUBJECT.

364. From whence are the materials of the human body derived? By what agencies are they wrought into food? 365. How is the subject of foods to be considered? What are simple aliments? compound aliments? 366. How are alimentary principles divided? Which will be treated first?

PAGE 207.—II. GENERAL PROPERTIES OF ALIMENTARY SUBSTANCES.

1. PRINCIPLES CONTAINING NO NITROGEN.—367. What is a solution? When does water dissolve substances most rapidly? When saturated with one, will it dissolve others? Give some examples of the extent of its solvent power. How does heat affect solution? What exception is mentioned? 368. Why should solids be crushed before solution? Why placed at the top of the liquid? 369. How much ammonia does water dissolve? How is soda water prepared? 370. What causes the difference in natural waters? 371. What are the contaminations of rain-water? When is it most impure? What is said of snow-water? 372. Why are boiled waters flat to the taste? 373. When does water putrefy? 374. What living beings are found in water? Do they exist in all water? What is said of acid and alkaline water? 375. Of what use are these beings in water? 376. Describe how rain-water becomes charged with mineral matter. Give instances of its varying quantity. 377. What are the minerals in spring and well water? When will water dissolve limestone? 378. What is hard water? soft water? 379. How may water act upon lead and not be injured? Give an example. What is the effect if much carbonic acid be present? What kinds of water should not pass through lead pipes? What is said of iron pipes? 380. In the absence of wells and springs, how may we supply our selves with soft water?

STARCH.—381. What is starch? Where is it found? How may it be separated? 382. What substances contain most of it? 383. What is said of the size of the starch grains in flour? How much do they vary in size from different sources? 384. Describe their appearance. How do they aid in detecting adulterations? 385. What is sago? 386. What is tapioca? 387. What is arrow-root? 388. How is corn-starch obtained? 389. What is the composition of starch?

SUGAR.—390. Where is sugar found? How much do the different vegetables yield? 391. What is grape sugar? 392. How may sugar be produced artificially? 393. How is honey obtained? 394. What is the best honey? What is its composition? 395. From whence do we get cane sugar? 396. State clearly the difference in origin of cane and grape sugar. 397. How do they differ in composition? in their properties? 398. What is the difference in their solubility? in their sweetening power? 399. How is brown sugar obtained from the cane juice? 400. What does brown sugar consist of? 401. What is said of the presence of grape sugar in cane sugar? 402. How may we find animalculæ in brown sugar? What contains most? 403. What is molasses? What are its properties? What are sirups and sugarhouse molasses? 404. How is sugar refined? 405. How is candy made? What are its common adulterations? What substances are used in coloring it? What is said of them? 406. What does Dr. Hassal say of the danger of using them?

GUMS.—407. What are the properties of the gums? 408. How may gum be made artificially? What is dextrine? 409. What is the composition of gum? What is its dietetical value?

OILS.—410. How are the oils divided? What are the properties of the fixed oils? Of the volatile oils? 411. How are they obtained? What is said of their consistency? 412. Give the proportion of oily matter in some of the leading articles of diet. 413. What is there remarkable in their chemical composition? For what do they seem specially adapted?

VEGETABLE ACIDS.—414. In what state do acids exist in plants? What is their composition, their nutritive value? 415. What is malic acid? What is the effect of culture upon it? 416. What is citric acid? 417. Where is tartaric acid found? For what is it used? 418. What are the properties of oxalic acid? 419. What is pectic acid? What are its properties? How does boiling affect it? What is said of jellies and jams? 420. What are the properties of acetic acid? How is it easily obtained? What kinds are most prized?

2. PRINCIPLES CONTAINING NITROGEN.—421. In what form are we all familiar with albumen? How may it be separated from the juice of plants? Where else is it found? 422. What is its composition? 423. At what temperature does it coagulate? What is the effect of diluting it? By what other means may it be coagulated? 424. How may vegetable casein be obtained? how animal? Do they differ? What is their composition? 425. What is animal fibrin? How is it obtained pure? What is its appearance? How may it be obtained from vegetables? 426. How is crude gluten obtained? What are its properties? What may be separated from it? 427. What flesh contains most fibrin? How does its character vary? 428. In what are all these substances alike? How do they differ? 429. What is gelatin? What is said of it? What is glue? Isinglass? What are the uses of gelatin? 430. What is said of the names given to these substances? Explain them.

3. COMPOUND ALIMENTS—VEGETABLE FOODS.—431. How are the compound aliments naturally divided?

GRAINS.—432. What is the composition of wheat? What causes it to vary? 433. What is the most valuable portion of food? What is said of the amount of gluten obtained by different chemists? What is thought to be about an average? 434. How does gluten differ in quality? How is the quality of flower determined by dealers? Describe Boland's invention? By its use, how are flours found to differ? 435. What are macaroni and vermicelli pastes made from? What wheats are best for this use? What are the qualities of good macaroni? 436. How is the difference in plumpness of grain in different wheats produced? How does the proportion of water in wheat differ? 437. Describe the process of grinding. 438. What is the structure of the wheat grain? Describe the husk. How are the other elements of the seed distributed? 439. Explain Fig. 93. 440. How are these different substances affected by the millstone? 441. From these statements, what follows in regard to quantity of bran? What is the composition of bran? What is the use of excess of oil in the husk? 442. How do white and

dark-colored flowers differ in composition? Describe the marks of good flour. 443. What is said of evaporation from wheat? 444. How does age affect flour? How does grinding affect its composition? Why should it be quickly cooled and dried? Why is freshly ground flour recommended? 445. What is farina? What are its properties? Composition? 446. What are the mineral constituents of wheat? Which is the most abundant and characteristic? How are they diffused? What is said of their importance? 447. How does rye differ from wheat? What is said of its husk? Of its gluten? Of its analysis? 448. For what is Indian corn distinguished? What is its composition? What is samp? Hominy? Why does it not keep well when ground? 449. What is said of oats? For what is it distinguished? What is its composition? What is *avena?* Why has the meal a rough taste? What are grits? How are they used? 450. What is the composition of barley? What is pot-barley? pearl-barley? 451. For what is rice remarkable? What is said of it? 452. What is said of buckwheat?

Leguminous Seeds.—453. What is said of the nutritive power of peas and beans? What is the composition of peas? Why cannot their meal be made into bread? 454. What is the composition of beans? 455. What is said of the ash?

Fruits.—456. For what are fruits prized? What is their general composition? How does ripe differ from unripe fruit in composition? Why do they decay so easy? Why do we know so little of them? 457. What is said of apples? What blacks the knife in cutting apples? What is the proportion of water to dry matter in apples? In melons? What is the dry matter of melons composed of?

Leaves, Leafstalks, etc.—458. What is said of leaves as the food of animals? What of their nutritive qualities? 459. How much gluten does dry cabbage contain? How much water does it lose in drying? What is said of its decay? 460. What are the properties of lettuce leaves? Water-cress? Horseradish? What is said of greens? What is the composition of rhubarb stalks?

Roots, Tubers, Bulbs and Shoots.—461. What is said of water in the potato? What is the average amount they contain? 462. How much starch do they contain? How does the time of year affect the quantity? 463. What is the form of the nitrogenous matter in potatoes? How much do they contain? 464. What are the remaining constituents of the potato? 465. What is said of its analogy to the grains? What is asparagin? What are the results of the analysis of its ash? 466. What is the proportion of nutritive matter in the onion? To what is its odor due? 467. What is the composition of beets? 468. What do we know of turnips, carrots, and parsnips?

Compound Aliments—Animal Food.—469. What are the chief constituents of animal diet? 470. What is flesh-meat? Describe its structure. What is its composition? How much does the quantity of water vary in flesh? Of oil? 471. What gives flesh its red color? What is the juice of flesh? What does it consist of? What are its properties? What is kreatine? Kreatinine? 472. How does blood differ from flesh? What is the composition of bones? marrow? Skin, cartilage, and membrane? Tongue and heart? Liver? Brain? Stomach? 473. Describe the eggshell. What does the egg consist of? What does it weigh?

Milk.—474. What is milk? In what respect is it a solution? In what an emulsion? What is its specific gravity? Its taste when first drawn? 475. What is said of the proportion of its elements? 476. How does the kind of food consumed by the animal affect her milk? Why should there be change of diet? What is said of the effect of different foods upon butter? 477. How does the first milk after calving differ from that yielded afterward? 478. What time of year is most favorable for milk? What climate? What weather? What other causes are mentioned as affecting the milk? 479. How is cream formed? What does it consist of? 480. What advantage is there in skimming milk in five or six hours after setting it, and again afterwards? Why should it be set in shallow pans? What is said of temperature? 481. How is it that the milk last drawn from the cow is the richest? How much will the first and last drawn milk differ? 482. For what is the hydrometer used? What is said of the value of its indications? Describe

the lactometer. What is the average proportion of cream in milk? 483. What is the composition of the ash of milk?

PAGE 256.—III. CULINARY CHANGES OF ALIMENTARY SUBSTANCES.

1. COMBINING THE ELEMENTS OF BREAD.—484. Why is the art of cooking necessary? What are the chief agents employed in changing our food? What are the advantages of changing the cereal grains into bread? How is bread made? How is the process to be considered? 485. What is batter? Paste? Dough? What is said of the combination of water with the flour? What proportion of water will bread lose in thorough drying? How much of this belongs naturally to flour? How much is absorbed in mixing? What kinds of flour absorb most water? What is the amount supposed to depend upon? What circumstances increase the quantity? 486. What purposes does the water serve? What is the object of kneading? What is said of kneading by machinery? How may we know when the bread is sufficiently kneaded? 487. What is said of bread from simple flour and water? What is sea-biscuit? What two important characters does such bread lack? How may these be imparted? What element of flour makes this possible?

2. BREAD RAISED BY FERMENTATION.—488. What is the effect of moisture and oxygen upon the nitrogenized alimentary principles? What are putrefiable substances? 489. How are the non-nitrogenous aliments in this respect? How are they affected by contact with putrefying substances? What are ferments? Give an example of this action. 490. What is said of the amount of ferment as influencing the process? Of temperature? 491. What is lactic acid fermentation? Vinous? Acetous? What are the conditions of acetous fermentation? 492. What ensues if flour and water be mixed and set aside for a time in a warm place? How may a true vinous fermentation be established? What is such bread called? 493. What causes the rising? How does it take place? Is this true of all kinds of raised bread? 494. Why is leaven used? What is said of it?

3. PROPERTIES AND ACTION OF YEAST.—495. What is malt? How is yeast produced? 496. What is the appearance of yeast? What is the effect of drying? What has the microscope revealed concerning it? How does it act to decompose sugar? 497. How may yeast be made at home? 498. How is yeast made from potatoes? 499. What are the properties of hop flowers? What use are they in brewing? 500. Why is yeast often dried? What is said of mechanical injury to yeast? How is dried yeast prepared? 501. How may the bitterness of yeast be removed? 502. How may we correct its acidity? 503. Describe the process of raising dough by yeast. 504. What causes sourness in dough? How may it be removed? 505. What becomes of the sugar in flour when bread is made? Then, how is it that sugar is found in bread? 506. How much alcohol is produced in bread? What is said of the attempts to save it?

4. RAISING BREAD WITHOUT FERMENTATION.—507. What objections have been urged against fermented bread? What is said of them? 508. By what two methods is unfermented bread made? 509. Explain the changes that take place in raising bread with bicarbonate of soda and hydrochloric acid? What are soda powders? What other preparations are used? What is the difficulty with them all? What is said of sour milk and soda? 510. What is said of sesqui-carbonate of soda in raising bread? 511. Why should these substances be used only occasionally? How are they adulterated? What advice is given in their purchase? 512. How is puff paste made? How do eggs give lightness? 513. How is gingerbread made?

5. ALTERATIONS PRODUCED IN BAKING.—514. How is bread commonly baked? How should the oven be made? If the heat be too great or too little, what follows? What is the proper temperature of the oven? How may it be tested? 515. What weight does bread lose in baking? 516. What causes the swelling of the loaf? 517. What changes occur in the crust? How may a hard crust be prevented? 518. What changes occur in the crumb? 519. What are the qualities of newly-baked bread? What causes

staleness in bread? How is this proved? What further is said of the water in bread? 520. What are the qualities of good bread? What conditions will secure it?

6. Influence of foreign substances in Bread.—521. How does common salt affect bread? What is said of the use of alum? Of sulphate of copper? Carbonate of magnesia? 522. How is so much bad flour produced? How do these mineral substances act upon altered gluten? Is there any harmless substance that will do the same thing. 523. How is lime water made? How is it used? With what result? 524. What are its effects upon the consumer? 525. What is the effect of rice added to wheaten flour? Of rye? How is Indian corn chiefly used? What is said of Graham bread? Of puddings? 526. What is M. Mourie's new theory of bread-making?

7. Vegetable Foods changed by Boiling.—527. How does boiling differ from baking? 528. In what parts of edible vegetables is woody fibre found? How does boiling affect it? How may it be changed to nutritive matter? What is said of Autenrieth's experiments? 529. How does sirup differ from dissolved sugar? What is the effect of heating melted sugar to 350°? Of heating dry sugar to 400°? What are saccharates? 530. Explain Fig. 100, showing the breaking up of starch grains. How do heat and water together affect them? 531. How does the appearance of a mixture of starch and water change by heating it? When allowed to stand for some time, what does it become? How may the process be hastened? How is dry starch changed to dextrine? 532. How does starch occur in the potato? What makes potatoes mealy after boiling? When are they waxy? What is said of the different methods of cooking them? 533. Why is soft water recommended in cooking? When is hard water best? How may soft water be made hard? What vegetables cannot be boiled soft in hard water? What s said of boiling onions?

8. How cooking changes Meat.—534. What is the effect of moderate heat upon pure fibrin? Of still higher heat? How does boiling affect it? How does heat alter albumen? How may albumen be used as a clarifying agent? What proportion of albumen suffices to make its solution solid? How is fat affected by heat? 535. How is extract of flesh obtained? What are its properties? How may we change the taste of beef to that of fowl? 536. What is the first effect of heat upon fresh meat? In what three ways is heat applied in cooking meat? How are the losses in each mode stated? Why are they greater in baking and roasting? 537. Describe the best method of cooking meat. When is it underdone? When quite done? Why should the fire be hot at first in baking and roasting? 539. Why is the fibrin more tender in this method? Why is the flesh of young animals more tender than that of old ones? What is said of the size of the piece of meat as modifying its quality? 540. What is the object in making soups, broths, &c.? What is the best method? What is said of gelatin in soup? 541. What are Liebig's directions for the preparation of meat broth for the sick?

9. Preparation and properties of Butter.—542. What is the effect of heat upon milk? Upon cream? What is said of this butter? 543. What changes occur to the milk and cream in churning? 544. How should the motion in churning be regulated? 545. What is the length of time required for churning milk and cream? How does this circumstance affect the quality of the butter? What should be the temperature of the cream at the beginning of the process? Does it change during the churning? What is said of the use of the thermometer? 546. To what is the flavor of butter due? What is its texture? Why is it different in this respect from lard? What is said of *first-rate* butter? Of the absorbent qualities of butter and cream? Of the kind of food best for the cattle?

10. Preparation and properties of Cheese.—547. What is the curdling of milk? What causes it? 548. How is milk curdled artificially? 549. What is rennet? How is it used? To what is its action due? 550. What does the separated curd of milk consist of? What the whey? What sort of cheese does pure casein make? How does the cream of milk change it? What is said of the heat employed in curdling? Of the amount of rennet used?

Page 289.—IV. COMMON BEVERAGES.

1. Properties and preparation of Tea.—551. What is tea? How is the plant grown? 552. How are the different varieties produced? 553. What two classes include all kinds of tea? What is the real cause of difference between these classes? What is said of the effect of steam in withering fresh leaves? 554. Give the list of green teas of commerce. Of black teas. Explain the name, and give the origin of each of them. 555. What is the composition of tea? Which of these are soluble? What proportion remains insoluble? 556. What is the Chinese method of making tea? What does its composition seem to indicate as the best method? What is the appearance of a good decoction of tea on cooling? 557. If the water of tea be not boiling when poured upon the leaves, what do we get? How is it commonly? What were the experiments of Mülder and Peligot? What is said of variation in the composition of teas bearing the same name in market? How may the gluten be dissolved? 558. How are the green teas much adulterated in China? How do the English adulterate tea? How may these frauds be detected?

2. Properties and preparation of Coffee.—559. Describe the coffee tree and its seeds. How are they separated? 560. What is the best coffee? How does it differ in appearance from other varieties? 561. What is the composition of coffee as it comes to market? 562. What is the effect of roasting upon coffee? How are its bulk and weight affected? 563. What is said of the importance of careful roasting? Of covering the vessel? Of the temperature? 564. How does age affect coffee? How is it often spoiled? 565. How should it be ground? What is said of the fragrance of coffee? Of steeping and boiling? What is Dr. Donovan's method? 566. What is the effect of putting soda in the water of which coffee is made? 567. With what is coffee adulterated? What is chiccory? How is it adulterated? 568. How may the cheats in coffee be detected?

3. Cocoa and Chocolate.—569. What are cocoa beans? How are they prepared for use? What is their composition? 570. What is "flake cocoa"? Cocoa nibs? Chocolate? 571. How are these preparations used? 572. What are the qualities of good chocolate? What cheats are practised by dealers in chocolate?

Page 300.—V. PRESERVATION OF ALIMENTARY SUBSTANCES.

1. Causes of their Changeableness.—573. Why must food be easily changeable? What is said of gluten as an example? 574. What has been the idea of vital forces in the body? What is at present known? How do the changes going on in the living and lifeless body differ? 575. Upon what does the rate of change in aliments depend? What substances are most changeable? What is said of water as promoting change? Of temperature? Of the atmosphere?

2. Preserving by exclusion of Air.—576. How is it shown that air excites decay? 577. Does all decay require the presence of oxygen? How is this explained? 578. How does boiling arrest these changes? What is Appert's plan of preserving? 579. What does Prof. Liebig say of preserving aliments in air-tight vessels? 580. How is this done when the cans are soldered? 581. How, by Spratt's cans? 582. What suggestions are given to aid in their use?

3. Preservation at Low Temperatures.—583. What is the effect of a temperature of 32° upon the changes of aliments? Of a boiling temperature? Of still greater heat? 584. What is said of freezing as a means of preserving? What cautions are given? 585. What is said of cellars? Of refrigerators? Describe Lyman's refrigerator, Fig. 107. 586. Why are fruits so perishable? How do cellars preserve them? What precautions are necessary in gathering fruit for winter? What other modes of preserving fruits are mentioned?

4. Preservation by Drying.—587. How has nature provided for the retention of water in some of her products? 588. What is said of drying? How may it be effected?

What is said of drying by artificial heat? 589. How are succulent vegetables best preserved?

5. Preservation by Antiseptics.—590. What are antiseptics? Mention those in domestic use. What is the composition of common salt? What remarkable things are stated of it? 591. What are the sources of common salt? How may pure salt be known? How may it be purified? 592. How does salt act in preserving meat? What is the effect of brine upon flesh? 593. What beside water does salt extract from meat? Why is saltpetre used with salt? 594. What is said of salting vegetables? 595. How does sugar act as an antiseptic? What is said of weak solutions? 596. What is said of alcohol? Of vinegar? Of creosote? Of oil? Of charcoal?

6. Preservation of Butter and Cheese.—597. How may milk be preserved sweet? What is concentrated milk? 598. What is the composition of butter just from the churn? 599. Why is it worked mechanically? How may it be done? 600. What is said of the practice of washing butter? 601. What is rancid butter? How is it produced? 602. Why must butter be made air-tight in packing? 603. Why is salt added to butter? How does it preserve it? What other substances are used? What is said of them? 604. Why is old cheese best? What are the best conditions for the perfection of cheese? What changes take place in it? 605. How do eggs change by time? How may they be preserved?

Page 318.—VI. MATERIALS OF CULINARY AND TABLE UTENSILS.

606. What is the purpose of this chapter? 607. What is the chief objection to iron for kitchen vessels? What is said of these compounds? How should iron kettles be managed? What is this enamel? 609. How is all tin ware made? 610. Is metallic tin injurious to the system? What substances affect it? Is it much acted upon? How is common tin contaminated? 611. Why cannot zinc be much used? 612. What is verdigris? What other substances may be formed when copper is used in cooking? 613. What is said of the salts of copper? 614. What qualities commend this metal for kitchen vessels? How may it be protected? What is said of brass kettles? 615. What attempt has been made to form more perfect cooking vessels? What is remarked of them? 616. Of what is earthenware made? Why must it be glazed? How is this done? 617. What materials are used in glazing common earthenware? What are the qualities of this glaze? How can it be detected? What substances act on it? 618. Why does glazing sometimes crack? How may soft glaze be detected? 619. What is said of porcelain. Of what is it made? What are its qualities? Describe its manufacture. What is said of its permanence among clay wares? Of its beauty? How is it colored? 620. What precaution is given in the use of cements?

Page 324.—VII. PHYSIOLOGICAL EFFECTS OF FOOD.

1. Basis of the demand for Aliment.—621. What is a common thought of men respecting creation? What is the true idea about it? 622. What is said of our ability to understand our own organization? 623. How do we maintain our identity through constant changes? 624. By what calculations is the extent of change going on in the body shown? 625. State the case of Thomas Parr. 626. Why must such an amount of matter be taken into the system yearly? How is it in the growing period of life? What is the relation between waste and supply in old age? In adult life, what changes are perpetually carried on in the system? 626. What important questions occur in relation to these changes? What is said of the materials introduced into the body, and of the agent that acts upon them? How do we influence the nutritive processes that take place in our bodies? 627. What is said of the beneficent use of hunger and thirst? In what do they consist? 628. How will the subject be considered?

2. First stage of Digestion—Changes of Food in the Mouth.—629. For what purpose is all food destined? Of what does the blood consist? What then must occur to the food before it can become blood? What is digestion? 630. In what state is the

food introduced into the mouth? Describe the mechanism for reducing it still finer. 631. Why is mechanical action insufficient? What is the saliva? What conditions produce a flow of saliva? 632. What are the properties of saliva? What is the "tartar" of teeth? Describe the different salivas. 633. What are the offices of saliva? What part of our food does it act upon? What practical inference follows from this? 634. What is said of careless, hasty eating? How does the state of mind affect the digestion of food? 635. What is the effect of profuse spitting?

3. Second stage of Digestion—Changes of food in the Stomach.—636. What becomes of the food as it passes from the mouth? Describe the stomach? How does it vary in different animals? 637. How many coats has the stomach? How do they differ? 638. What movements of the food occur in the stomach? How are they produced? 639. What are the stomach follicles? Explain Fig. 117. 640. What is the purpose of this arrangement? 641. What is said of the necessity of regular times of eating? 643. What are the properties of gastric juice? How soon after eating does digestion get fully under way? 644. How does the digestion of the stomach differ from that of the mouth? 645. How may artificial gastric juice be prepared? How does the digestion of the stomach differ from artificial digestion? 646. What is pepsin? What can it not do? 647. How does gastric solution differ from common solution? What is meant by the term *peptone?* 648. What follows when the alkaline saliva enters the stomach? 649. How have people erred in estimating the quantity of gastric fluid secreted? What is now believed about it? 650. What is meant by digestibility of foods? What is said of Dr. Beaumont's investigations? In regarding the times of digestion, what consideration beside the solubility of aliment must be taken into account? What are some of the results of Dr. Beaumont's observations? 651. How do the liquids of the stomach get into the blood? How is this proved?

4. Third stage of Digestion—Changes of Food in the Intestines.—652. What is the duodenum? What fluids enter it? How do they differ from gastric fluids? 653. What portions of food are affected by these juices? What changes occur? What provision is made for undigested albuminous matter that has escaped from the stomach? 654. In what ways are substances absorbed from the intestines? How do the lacteals perform their office? What is the course of these lacteal fluids? 655. What foods are most laxative?

5. Final destination of Foods.—656. How much blood has an average-sized man? 657. What causes the composition of the blood to vary? What is it stated to be. 658. How does the blood appear when viewed by the microscope? What is said of these globules? 659. How is the development of power shown to be the leading purpose of the body? What is said of the creation of force? 660. What are the chief elements of our food? Through what agency do they become food? What force acts upon the vegetable kingdom? Is the case different when we eat flesh? In this view, what is said of the blood? 661. In what state does force reside in food? How is it made active? What is the nature of these changes? 662. How is the necessity of the constant introduction of food shown? What is starvation? 663. What is combustion? How is the action of oxygen in the body shown to be combustive? 664. How do we find foods divided in reference to their destination? What is said of the difference in combustibility of different aliments? 665. What is said of the combustibility of nitrogen? 666. What names are given to non-nitrogenous food? To the nitrogenous? How must these distinctions be regarded?

6. Production of Bodily Warmth.—667. Why must the body possess a fixed temperature? What is the temperature of health? What is said of the power of the body to maintain it? 668. In how many ways does the body lose heat? How much is lost by evaporation? 669. How is the supply of heat kept up? What is the physiological difference between warm and cold-blooded animals? When no food is taken, how is warmth sustained? What occurs in plants when they exhale carbonic acid? 670. How does the experience of those who ascend high mountains accord with this view? How

is it with those who go down in diving bells? 671. What is the final destination of most of our food? When do we require most heat-producing food? Among foods, which has the highest calorific power? How do other foods rank? How are they compared? What is said of the use of bread in the arctic regions? What was Dr. Kane's experience? How is it in warmer regions? 672. In very hot weather, how is the temperature kept down? 673. What is said of houses and clothing as replacing food? 674. At what times of life does cold affect the body most? What has been observed in hospitals for the aged? 675. What relation is there between periods of rest and eating, and the daily changes of temperature?

7. Production of Bodily Strength.—676. What is the annual amount of heat produced by an adult man estimated to be? What is said of the force required to execute the involuntary motions of the body? 677. What is said of the waste that accompanies this expenditure? How much does the body lose daily? 678. From what part of food is flesh formed? What is said of albumen? How is it in the bird's egg? What is the double purpose of albuminous food? 679. Explain how oxygen acts upon the tissues. In what sense are nitrogenous matters heat-producers? 680. When waste and supply are equal, what takes place in the body? When waste exceeds supply? When supply exceeds waste? 681. What is the relation of common salt, tea, &c., to nutrition. Why are they not true foods?

8. Mind, Body, and Aliment.—682. What is the relation of mind to matter? What is said of the brain? 683. What material changes occur accompanying the manifestation of mind? What provision is made for its nutrition? If this is interrupted, what follows? How does starvation affect nervous tissue? 684. What measure has been found of the amount of exercise a part has experienced? Can these results be fully depended upon? 685. What is said of the exhausting effect of mental exercise? 686. What remarkable properties has phosphorus? How does the proportion of phosphorus in the brain vary in different classes of persons? In what form is it found? 687. What is said of special brain nutriments? What does Liebig say in this connection? 688. What important considerations of diet should govern brain-workers? 689. What is said of brain excitants?

9. Influences of Special Substances—Saline Matters.—690. How were the mineral elements of plants once regarded? What is now known? 691. What is a salt? A neutral salt? An alkaline salt? An acid salt? What does the ash of foods consist of? How are the acids changed in burning? What proportion of salts is found in celery? Sallad? Cabbage? 692. What becomes of the mineral parts of food when taken into the system? 693. What is said to be the state of all the animal juices? How is it with the blood in this respect? What properties of the blood depend upon its free alkali? 694. What is the character of flesh and its juices? Do acids or alkalies predominate in the system? What are the chief flesh acids? What do these conditions of blood and flesh juice seem to indicate? 695. Where and to what extent does common salt exist in the system? What are its offices? What does it yield by its decomposition? What is said of the salts of sodium and potassium in blood and flesh? 696. How does salt escape from the system? How is the supply kept up? What is said of its presence in vegetables? Of the natural demand for its use? 697. What are the effects of eating too little salt? What is scurvy? What are anti-scorbutics? How does flesh differ in the proportion of salt it contains? 698. What compounds of soda and potash are used in making bread, and how do they differ? What are their relations to the system? When are they useful, and when harmful?

Liquid Aliments.—699. How much of the body is water? In what forms and to what extent is it taken? 700. In what conditions is it found in the body? 701. How do plants and animals differ in their relations to water? 702. How does water affect the digestive process? 703. In Dr. Bocker's experiments upon the use of an excess of water, what conclusions did he reach? 704. What is said of the relation of tea and coffee to foods? 705. How do the different elements of tea affect the system? What are the con-

clusions from Dr. Becker's experiments? 706. What is the effect of empyreumatic substances upon digestion? What will people whose stomachs are sensitive, observe to be the effect of strong coffee? How is tea different? 707. What are Lehman's statements on the influence of coffee? 708. What is said of chocolate? 709. What substances are found in the various liquors? Upon what does their commercial value depend? What is the main element of them? 710. How does the action of alcohol compare with that of water in the system? 711. What is said of its power to nourish tissue? 712. Why is it not a respiratory aliment? 713. What were the results of Dr. Becker's experiments with this substance? 714. How do the statements of Moleshott, Chambers, and Liebig, upon the use of this substance, compare with each other? 715. How are the stimulating effects of these beverages described? 716. What is said of milk? How does milk from different species of animals differ? How does skimming alter the dietetical qualities of milk? 717. What kinds of soup are strength-giving? What is said of gelatin? Why may it be good for invalids?

Solid Aliments.—718. Why must starch be cooked? In what form is starch best digested, and why? 719. What changes does sugar undergo in the system? What is said of its injuring the teeth? 720. What purposes does gum serve in the body? 721 What proportion of oil do we obtain from different foods? How may the uses of fats be considered? 722. What is the relation of fat to bodily movement? To beauty of form? To swimming? 723. What is said of the action of fat in the stomach? How does the distribution of fat in meat affect its digestibility? Why are fish and poultry easily digestible? How is it when they are dressed with fat? 724. What changes are produced in the fats by heat? Why are cakes less digestible than bread? What does Dr. Pereira say upon the use of the oils? Dr. Chambers? 725. How does fat aid in the nutrition of the body? 726. What is tubercular consumption? What is the cause of it? Why have oily matters been prescribed for this disease? What is said of its prevention? 727. How are bilious conditions produced? Rheumatic? Scrofulous? Scorbutic? 728. In what state is meat most digestible? How does veal and lamb broth differ from that of beef and mutton? 729. What is said of pastry and puddings? Of boiled dough? 730. How do coarse and fine bread differ in composition, and in their effects upon the system? 731. How should beans and peas be cooked? 732. What is said of the healthfulness of vegetables? 733. What is the dietetical value of the potato? The turnip? The onion? 734. What is said of fruits? Of the apple? 735. What are condiments? 736. When regarded as an aliment, what are the qualities of cheese? What are they as a condiment? 737. What is the influence of vinegar upon digestion? Upon corpulence? 738. How do condiments act upon the system?

10. Nutritive value of Foods.—739. What would we infer of the purposes of foods from their composition? What is said of the power of the system to transmute food? 740. What must our diet contain? How must it be varied? 741. What does Fig. 112 represent? Explain it. Has the quantity of solid matter any relation to nutritive power? 742. What is the best that can be done in estimating the comparative value of foods? With what restrictions must this be taken? 743. Explain Fig. 122, giving the relative powers of the calorifient elements of food. Why is there no such table for the nutritive group? What is said of alcohol? 744. Why is an exclusive meat diet bad economy? What estimate has been made showing the advantage of starchy food in the case of a savage? What is said of bread in this relation? 745. What makes the nutritive elements of diet most expensive? When do the calorifient rise in value? 746. What does Fig. 128 represent? Explain it. What idea must be borne in mind in studying this diagram? 447. What makes the composition of milk an interesting study? How does the human infant differ from the young of all other animals? Why is the milk prepared for them richer in curd? 748. What are the advantages and deficiencies of wheat? How does wheat flour compare with milk and blood? 749. How much is the daily waste of tissue? How much food does an adult laborer require to restore this loss? What is the proper proportion of nitrogenous to non-nitrogenous matter? Why is bread a bad respiratory

aliment? How does instinct provide against this need? 750. How does wheat flour vary in composition? What is said of the relation of commercial and nutritive values? 751. What is said of the amount of bran separated in grinding now and formerly? Of the effect of bolting? 752. What must be eaten with lean flesh, and why? What combinations of food have the instinctive cravings of men prepared, and what do they illustrate? 753. Why are sago, &c., unfit for children's food? What do they require? What is said of the use of lime?

11. The Vegetarian Question.—754. What controversy exists upon the subject of diet? What does the vegetarian diet consist of? What do the advocates of vegetable diet insist on? What is replied by the friends of mixed diet? What course will here be pursued in reference to the subject? 755. What has formerly been believed of the power of the system to transform food? What is now known? 756. What is said of the identity of vegetable and animal principles? What does this seem to indicate? 757. What difference exists between vegetable and animal food? Why is flesh the most perfect of all aliments? How does it increase the activity of the system? What is said of its stimulating effects? Are vegetarians tempted to excessive eating? 758. What remarkable fact concerning the mineral constitutions of these two forms of food is mentioned? 759. What are the characteristics of human saliva? What does it indicate? 760. What is said of the relative economy of the two kinds of diet? 761. What is said of the diversity of diet that exists among men?

12. Considerations of Diet.—763. What circumstances influence the quantity of food needed? What is told of the Manchester manufacturer? 764. Why is it difficult to classify diet as low, high, &c.? 765. How should rules of diet affect us? What is said of diet scales? 766. What reason is given for eating slowly? 767. What considerations should fix our times of eating? Why should breakfast be early? Why is luncheon commended? Why are late suppers condemned? 768. Why should we not eat when tired? Why should little exercise be taken before breakfast? 769. What is said of the sympathy between brain and stomach? What is hence recommended? 770. Why should we rest after a full meal? 771. What bad results flow from excessive eating? 772. What is said of the necessity for prompt supplies of food? How does hunger affect the mind? 773. What relation is there between great exertion and hearty eating? What is said of the habits of students? Of Americans? 774. Why is a stiff regularity in the recurrence of dishes condemned? 775. What causes promote corpulence? What is a good diet for corpulent people? 776. What directions are given to nursing mothers? What is said of procuring and managing wet nurses? How may cow's milk be corrected for children? What directions are given in reference to their solid food? 777. What changes are going on in the system during childhood and youth? What food does this period require? 778. What should be the diet of middle life? 779. What changes are going on in the system as age advances? What do they indicate in regard to the food? What consequences may flow from neglecting these cautions?

PART V.—CLEANSING.

Page 422.—I. PRINCIPAL CLEANSING AGENTS.

780. What is dirt? How is it removed? 781. How does water act in cleansing? 782. What impurities are sometimes found in water? 783. How is water purified by subsidence? 784. How by filtering? 785. Describe the filter Fig. 124. What is said of charcoal as a filtering agent? 786. How may dissolved impurities be separated from water? How has the hardness of water been expressed? What causes the fur on the tea-kettle? Does the length of time of boiling affect the result? 787. What are the alkalies used in cleansing? What is said of the alkaline carbonates? Of aqua ammonia? 788. What is soap? 789. How is soap made? 790. What conditions produce hard, and what soft soap? 791. What is said of the water in soap? How does the solubility of soap vary? 792. What is Castile soap? Curd soap? How are fancy soaps made? Transparent soap?

Page 428.—II. CLEANSING TEXTILE FABRICS.

793. What is stated to be the general principle of cleansing? Why must the power of the alkalies be restrained? By what means is the dirt held to the garment? How is soap adapted to this state of things? 794. How may we test the hardness of water with soap? 795. Explain the difference in texture between woollen, cotton, and linen fibres. Why do the woollens shrink? How should they be washed? 796. What is said of the removal of spots? How is alumina used? What is French chalk? Ox gall? How does a portion act in removing stains? How may wax, resin, and pitchy spots be taken out? How, oil-paint stains? Coffee and chocolate? Fruit stains? Ink spots? Indelible ink?

Page 431.—III. CLEANSING THE PERSON.

797. Describe the structure and offices of the skin? 798. What are the oil glands? How do they protect the system? When the skin is neglected, how are these altered? What is Fig. 129? 799. Why must soap be used in washing the skin? What is said of its use? 800. What directions are given for washing the face? 891. What causes tartar to accumulate on the teeth? How may it be removed? What are the best tooth-powders?

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